School of Earth Sciences

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Dean David Manderscheld
Executive Dean
College of Arts and Sciences
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Dear Dean Manderscheid,

I am writing in my capacity as the Director of the School of Earth Sciences (SES) to endorse the proposal submitted by Michael Bevis, Steven Rissing, John Brooke, Sam White, Geoffrey Parker, Elizabeth Marschall and me for the acceptance of a team-taught, multidisciplinary GE course called Climate Change: Mechanisms, Impacts & Mitigation. The proposing team involves a teaching pool of two full professors from SES, two full professors from the Department of Evolution, Ecology and Organismal Biology, and two full professors and an assistant professor from the History Department. Climate change is one of the great issues facing humanity in the coming decades. There is a real need to educate the population on how the climate system actually works, what impacts a changing climate have had on past human populations, and what potential impacts there will be in the future. This course will address all these issues in a truly cross-disciplinary manner. The idea would be to have one professor from each of the three departments team up for each offering of the course. Michael Bevis has agreed to coordinate the first offering.

SES support of this proposal is dependent on CAS accepting the concept of proportional credit sharing (PCS), as described and justified in the proposal. In the opinion of most, if not all, of the proposal team, large-enrollment, multidisciplinary GE courses are only viable in the long term if they use this framework to assign credit for work done. Given the huge time and effort commitment required by the faculty to realize new, team-taught, multidisciplinary efforts of this kind, it seems reasonable to expect that the CAS administration to give credit to the contributions of each instructor.

We hope that this course will first be taught in the Fall semester of 2015. If this course proposal is accepted, there will be a great deal of preparatory work to be done for it during the Spring semester, including identifying a suitable multidisciplinary cohort of TAs selected from all three academic units, materials well in advance of the course launch. The course would require access to a very large instructional computer room for the recitations, and to a large lecture theater. Thanks for these considerations.

Yours,

WBLyons

W. Berry Lyons
Director, SES

THE OHIO STATE UNIVERSITY

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November 23, 2014

Dr. David C. Manderscheid
Executive Dean and Vice Provost
College of Arts and Sciences
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Dear Dean Manderscheid,

I am writing to express my strong support of the team-taught multidisciplinary General Education course, *Climate Change: Mechanisms, Impacts, & Mitigation*, proposed by professors Michael Bevis, Steven Rissing, John Brooke, Sam White, Geoffrey Parker, Berry Lyons, and myself. Building and offering a course on climate change that can reach students in all parts of the university will contribute to the University's ability to prepare students to become well-informed citizens. Not only will the proposed course provide an in-depth study of a globally important problem, it also will introduce students to the commonalities and differences in the analytical processes used in earth science, biology, technology, and history. The very multidisciplinary team has not only laid out an excellent GE course, but also has proposed solutions to managing the collaboration over time and dealing with the attribution of enrollment credit in multi-unit teaching collaborations. The proposed "Proportional Credit Sharing" method solves the problem of how to assign credit to the many different departments in a multidisciplinary course, specifically by sharing enrollment credit hours in proportion to the number of lectures given by faculty from each department. I think this is an essential part of the proposal.

Thank you for considering this proposal.

Sincerely,

Elizabeth Marschall

Elizabeth Marschall
Professor and Chair

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November 18, 2014

Executive Dean David Manderscheid
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CAMPUS

Dear Dean Manderscheid:

I am writing to endorse the proposal for a new team-taught course titled "Climate Change: Mechanisms, Impacts & Mitigation." This course is truly interdisciplinary in conception, structure, and pedagogy. It will be team-taught with faculty from the School of Earth Sciences, the Department of Evolution, Ecology and Organismal Biology, and the Department of History. Due to the multidisciplinary nature of this course and the effort on the part of faculty to conceptualize and institute the course, my endorsement is contingent on the College accepting proportional credit sharing (PCS) as outlined and justified in the proposal.

The faculty members from the Department of History constitute an internationally-known constellation in climate history. Moreover, all of them are affiliated with the Climate, Security, Health, & Resilience Initiative of the Mershon Center and Byrd Polar Research Center. Geoffrey Parker, renowned for many publications in his distinguished career, is recently the author of the prize-winning opus, *Global Crisis: War, Climate Change & Catastrophe in the Seventeenth Century*. John Brooke, originator of our History 2700, "Global Environmental History," and also a multiple prize-winning author, recently published his path-breaking *Climate Change and the Course of Global History*, the first global study by a historian "to fully integrate the earth-system approach of the new climate science with the material history of humanity." John also is an Adjunct Professor in the Department of Anthropology. Sam White's *The Climate of Rebellion in the Early Modern Ottoman Empire* explores the far-reaching effects of severe cold and drought in the Middle East during the "Little Ice Age" of the sixteenth and seventeenth centuries. It has won three prizes for the best book in Middle East and Turkish studies. Sam's 2011 article in *Environmental History* won two prizes.

"Climate Change: Mechanisms, Impacts & Mitigation" will enhance our department's programs in several ways. As a GE course with broad appeal, it will reach large numbers of students, including many STEM students who will learn much about the value of historical thinking. We expect that many students taking the class with interest in human affairs will give more thought than they might have expected to the opportunities in the history major and minor. The course will add to our already strong reputation in environmental history, attract outstanding graduate student assistants, and help us maintain leadership in the field. Furthermore, it will demonstrate the value of historical study within the Arts and Sciences and contribute to the College's Discovery themes.

Sincerely,

Peter L. Hahn
Professor and Chair

A Proposal for a Team-Taught, Multidisciplinary General Education Course on

Climate Change: Mechanisms, Impacts & Mitigation

Michael Bevis[1], Steven Rissing[2], John Brooke[3], Sam White[3], Geoffrey Parker[3],
Berry Lyons[1] and Elizabeth Marschall[2]

1. Introduction

We propose a new general education (GE) course on climate change, which is one of the defining issues of our time. We would like to initiate this course in the Arts and Sciences College in the Autumn semester of 2015. This course would be very unusual in that

- despite its focus on a scientific topic of considerable technical complexity, it should be understood by 1st or 2nd year undergrads unlikely to choose a career in STEM
- it must be valuable to STEM students as well
- it will be *highly* multidisciplinary, involving almost all earth science disciplines, biology in the broadest sense , technology, historical and economic perspectives
- rather than broadly surveying a single scientific discipline, like most science GEC courses, it will examine a single problem - climate change - from many perspectives

Interdisciplinary and multidisciplinary GE courses are on the pedagogical radar screen at OSU and across the USA. For example, physicist Karl Hess, a member of the NAS and NEA, and author of *Working Knowledge: STEM Essentials for the 21st Century* (2012) believes that "STEM education [should integrate] important historical knowledge, modern developments, and today's hot topics", and that "STEM texts need to treat the broad field as a whole and not as a collection of different subjects. Teachers need to individualize that knowledge for students and connect it to such important topics as global warming and renewable energy". The desirability of developing and promoting multidisciplinary GE courses was a key theme developed in the ASC GE Review of ~4 years ago, though this proposal was later sidelined by quarter to semester conversion at OSU. But in his memorandum of March 13, 2014, Executive Dean Manderscheid explicitly called for proposals for new team-taught, interdisciplinary or multidisciplinary courses in ASC. Our proposed course could be part of this broader initiative.

Our primary concern here is in explaining our vision for a multidisciplinary GE course on climate change. However, we are well aware that despite the fact that multidisciplinary GECs have been on the academic radar screen for *at least* 5 years, they are still very rare at American public universities, and, as far as we can tell, are non-existent at OSU. We believe that there are systematic reasons for this, and that overcoming these barriers will require the development of novel administrative mechanisms, as well as innovations in pedagogy *per se*. We hope that our suggestions in

[1] Earth Sciences, [2] Evolution, Ecology & Organismal Biology, [3] History

this regard might be useful to other groups contemplating the development of multidisciplinary GECs.

2. Motivations and Goals

Climate Change is one of the most important challenges facing our civilization. It is vital that scientists, especially academic scientists, find ways for ordinary citizens to understand the basic science of climate change, assess our ability to make accurate predictions, and examine the implications for global sustainability. Our students are young citizens, and this topic is especially relevant in that context. In order to assess the credibility of climate change predictions it is necessary to develop a basic understanding of the climate system, which involves the atmosphere, the hydrosphere, the cryosphere and the biosphere. Climate change means much more than global warming. To understand the impact of these broader changes, such as intensification of the water cycle and ocean acidification, it is necessary to explore a wide range of biological consequences as well. We refer to biology in the widest sense, including agriculture, coral reef ecology, pathogens and disease vectors, etc. Even then, it is hard for an average person to assess the socio-economic impacts of such a complex set of severe problems acting in concert, and here an historical analysis of past environmental disasters is very helpful. Having presented the terrible risks associated with accelerating CO2 production and climate change, a study of mitigation, especially via a transition to a lower carbon future, will be fully motivated. But understanding that transition requires an assessment of the energy industry and its trends, an appropriate role for government, and economic constraints and mechanisms (e.g. carbon taxes). A historical account of past changes in principal energy sources, and of similar socio-economic transitions, is highly relevant too.

Promoting a useful understanding of scientific method among non-scientists. Traditional GEC science courses – introductory survey courses - are of great value to any student heading into a STEM career, and prove valuable to many non-STEM students as well. But it is also true that many students not oriented towards a STEM career find it difficult to relate to standard GE science courses. Many such students persuaded themselves years before arriving at OSU that 'I can't do math', 'I hate science', etc., and such attitudes, along with the attendant anxieties, can prove to be a self-fulfilling prophecy. The frequent shifts of focus common to most basic survey courses may also prove problematical to the uninterested and disengaged – the course as a whole may parse for them like a shopping list or dictionary. However, many of these scientifically-disinclined 'poets' are already interested in climate change. A course that allows them to explore this hot topic from many different angles should also provide them with better and deeper insights into the nature of science. We'd prefer that the rhythm and trajectory of the course feels closer to that of a mystery novel, rather than a dictionary, drawing the students towards greater understanding while maintaining or expanding their interest levels. For all students, including those already oriented towards a career in science or engineering, examining a broad scientific attack on a real-world problem should provide useful and interesting insights into how a great deal of modern science is actually pursued. Achieving these goals will be easier if we can weave historical, economic and political threads into the scientific and technological narrative.

3. *Credit sharing: Overcoming an institutional barrier to multidisciplinary teaching*

It is notoriously difficult to persuade college curriculum committees to approve truly multidisciplinary GEC courses – at least on terms considered satisfactory by the prospective teachers. One important reason for this is the concern about which of the several departments providing instructors will reap the student credit hours. This is a particularly pressing issue at OSU, given its present budget model. We propose to defuse this problem by asking the OSU or ASC administration to approve and implement a scheme whereby departments share the student credit hours in proportion to the number of lectures given by their instructors. We consider such '**proportional credit sharing'** the fairest basis for collaboration, since each department gets out in proportion to what it puts in. We believe that this mechanism is a necessary condition for the successful growth in large-scale multidisciplinary teaching in general. We suggest that a 'lecture count' for each participating department should be submitted to ASC's academic administrators around the same time as the student grades.

4. Course Scope

We wish to explain the modern scientific consensus on the causes and mechanisms of climate change, and to explore its present and projected impacts. Certainly we want to explain the greenhouse effect in some detail, which is quite difficult without resorting to mathematics. This agenda includes addressing the apparent paradox - much seized on by climate change deniers - that during the Ice Ages temperature changes drove CO2 changes, whereas now CO2 changes are driving temperature changes. The key concept is that of disturbing or perturbing an existing equilibrium. The main present-day disturber of equilibrium is anthropogenic CO2 production, in large part due to the rising use of fossils fuels. That driver was not a factor during the Ice Ages.

We want our students to perceive the complex nature of the climate system, including the vital roles of the oceans, which have taken up about one third of all anthropogenic CO2 and about 90% of the excess heat energy generated by an enhanced greenhouse effect. Air-sea interactions tend to be cyclical, and this complicates the space-time development of climate change. It also explains the warming hiatus or 'pause' – another favorite topic of climate change deniers. Most of the 'missing' warming in the last 15 years has been taken up by subsurface ocean water rather than by the atmosphere.

We will document and explain ocean acidification, which is a consequence of C02 uptake by the oceans. Some marine biologists view ocean acidification as the most dangerous global change of all. We will explore the dangers posed and the damage already done to coral reefs and their ecosystems. When oceanic acidification and/or ocean warming act in concert with other factors, such as phosphate or nitrogen run-off (from fertilizers, industrial animal farming, etc.), then other negative developments (e.g. algae blooms) can enter the picture.

We wish to explain warming-induced intensification of the water cycle, which means more droughts, more flooding, more severe weather, etc., both from the physical point of view, and in terms of what it means for biodiversity, agriculture, water resources, disease vectors, etc. More droughts implies more famines, more fires, more migrations, etc. In some parts of the world it could lead to starvation.

Some topics, such as the <u>accelerating</u> melting of Greenland's ice sheet during the last decade, serve to evoke the spatial heterogeneity of global warming, and show how melting arises in response to both atmospheric and oceanic warming, and in response to both climate trends and climate cycles. Ice sheets and mountain glaciers also preserve long records of atmospheric chemistry and temperature, an achievement widely associated with OSU's Lonnie Thompson and Ellen Mosely-Thompson. Greenland provides some vivid examples of economic, social and biological impacts (including the impending extinction of the polar bear).

We will explore the causes and likely impacts of sea level rise, which is driven in large part by thermal expansion (i.e. a warming ocean) and mass transfer from ice sheets and mountain glaciers (i.e. melting ice). The loss of mountain glaciers in some countries (e.g. Peru and Bolivia) provides a direct and immediate threat to water resources used by millions of people.

We would like to incorporate historical analyses, such as those made by OSU's John Brooke, Geoffrey Parker and Sam White in their book s "*Climate Change and the Course of Global History* ", "*The Global Crisis: war, climate, and catastrophe in the 17th-century*", and "*Climate of Rebellion*", two of which focus on crises induced by the Little Ice Age, a global cooling event. Using the past as a means to anticipate our future, we can imagine how global warming's tendency to dry out many landmasses could bring about severe shortages of water, agricultural collapse, mass migration and even wars largely focused on water and food resources.

In the final part of the course we would consider how societies could, if they choose, modify their mix of energy sources, and promote better energy efficiency, and alter their path of development so as to slow down or mitigate climate change. This would not be limited to simplistic 'apple pie' recitations of the merits of renewable energy. We want to acknowledge and explore some of the complex economic issues associated with energy usage, including the historical coupling of economic development and energy use. We would also address the issue of whether or not shale gas, which is very often characterized as environmentally negative, might serve as a useful transitional fuel to a safer energy future, due to its much smaller carbon footprint relative to coal and tar sands. We will also discuss possible adaptations to climate change.

Historical analyses of past shifts in energy sources and energy technologies, and other major technological 'sea changes' are also very illuminating.

5. Approximate breakdown of topics and disciplinary contributions

This 4 credit hour GE course would involve lectures and a weekly recitation.
Lecture section: Three 55-minute lectures per week (MWF – holidays) split between the 3 disciplines: Earth Science (E), Biology (B) and History (H).
Recitation section: 1 hour/week of recitation led by TAs coming from earth science, biology and history (see section 10).

Preliminary course description (lesson plan for lecture section of course)

The Climate System	**7**
Climate versus Weather	(1) E
Solar radiation and the Greenhouse Effect	(1) E
Atmospheric and oceanic circulation	(1) E
The water cycle	(1) E
The carbon cycle	(1) **B**
Climate, biology and agriculture	(1) **B**
Climate, culture and economics	(1) H
CO2 and Climate change	**8**
CO2 – the Keeling curve and the ice core record	(1) E
Intensification of the Greenhouse Effect	(1) E
Ocean acidification (direct uptake by oceans of CO2)	(1) **B**
Predicted climate changes	
Global Warming	(1) E
Intensification of the water cycle	(0.5) E
Intensification of severe weather	(0.5) E
Ice loss and related loss of water resources	(0.5) E
Sea level rise	(0.5) E
Biological Responses to Climate change	**9**
Biodiversity – Terrestrial and Marine	(3) **B**
Agriculture	(3) **B**
Drought, fire and landscape	(1) **B**
Plant and Animal Migration	(1) **B**
Disease and Disease Vectors	(1) **B**
Historical Experiences of Major Climate Change	**6 H**
Collapses of ancient cultures	(1)
Vulnerability and crisis in traditional societies	(1)
Climate and conflict	(1)
Climate and culture	(1)
Adaptation and resilience through history	(1)
Climate and weather in the modern age	(1)
Effects on modern human infrastructure	**1 H**
Times scales for development and modification of cities,	

transportation, agriculture, aquaculture, food systems	
The Socio-Economics of Managing Risk (inc. Insurance)	**1 H**
Mitigation and Adaptation	
The energy industry and its trends	**5**
Fossil Fuels & Nuclear Energy	(2) E
Renewable Energy	(2) E
Energy Efficiency	(1) E
Transition to a low carbon future	**5**
Is it possible to do this fast enough?	(1) E
Historical transitions of a similar character	(3) H
-Science and politics: lessons from recent global issues	
-Environmental problems and engineered solutions	
-Past energy transitions & other technology transitions	
Economic complexities and trade-offs	(1) E
Summary and Discussion	**1 E**

Total number of lectures identified in table above: 41

Disciplinary Contributions (# lectures) – approximate count of E, B and H lectures.

Earth Science	17	(41.46%)
Biology	12	(29.27%)
History	12	(29.27%)

6. *Lecturers and Guest Lecturers*

We believe that multidisciplinarity poses special difficulties as well special advantages and opportunities. This course will be team taught by an earth scientist, a biologist and a historian. There will have to be a great deal of coordination between the team members to ensure continuity of terminology, integration of material, and parallelism of intent. We strongly believe that it this course should be taught by full time faculty members, and not by adjuncts, and that team membership should change, from one offering to the next, in a highly controlled fashion (section 10).

We are considering that each professor might invite one or two guest lecturers into the class. In the event that these lecturers come from OSU we would wish their departments to be assigned credit using the proportional credit sharing mechanism discussed in section 3. Otherwise the credit remains with the host professor's department. For example, it is possible that the Dept. of Geography might provide guest lectures on ice cores and/or paleoclimate in which case they would be assigned credit for one or more of the lectures led by the faculty member from the School of Earth Sciences.

7. *GEC Status Sought*

We wish to develop a 1000-level course that students can use to satisfy GEC credit hour requirements in physical science, biological science or history (as they choose). We request an Earth Science course number of 1911. We insist that sharing a course so listed will not work unless all teaching credits are split between the collaborating departments, using the **proportional credit sharing** concept explained in section 3.

Although the recitation section will incorporate a virtual multidisciplinary laboratory concept (section 10), for administrative purposes it is a recitation and not a lab because students earn the extra credit hour in return for one hour's attendance per week.

8. *Student Communication Element*

In keeping with recent directives to foster verbal and written communication skills in the undergraduate body, we plan to use the final and extended recitation period for a poster session, in which each student presents a poster on some theme related to the course. Each student will spend 40 minutes in front of his or her poster, and up to 80 minutes visiting other posters. We are may open this session up to a wider audience.

9. *Required Texts and Other Readings*

Required Reading:

'Climate Change: Evidence & Causes'. A short overview published by the Royal Society and the US Academy of Sciences. 33 pages.
IPCC 5 'Physical Science – Summary for Policy Makers'. 27 pages.
IPCC 5 'Impacts – Summary for Policy Makers' (being reformated, ~ 30 pages)
IPCC 5 'Mitigation – Summary for Policy Makers'' (being reformated, ~ 30 pages)
DOE 2012 Renewable Energy Data Book. 128 pages.

Note: these documents are all free. The first four are very short. We also plan to make these and other resources (including lecture materials) available to the students as PDF files. The DOE document has a rather misleading name because it contains a great deal of information on fossil fuel and renewable energy sources, and on the patterns of energy usage. It is a long report, but mostly graphs, charts and tables that are very easy to assimilate. We want students to read the four short documents. We want them to be able to dip into the DOE report, and use it as a resource in their work.

Use of Newspaper Reports:

We will recommend that students purchase a several month digital (or paper) subscription to a major newspaper, such as the New York Times, the Washington Post, The Economist, or their home town newspaper, and collect and pool all stories related to climate change that appear during the semester the course is given, ideally in the form of a digital 'scrap book'. Those articles may provide students with ideas for the end-of-course student poster session. This activity will be especially relevant to students electing the optional lab/recitation component (see section 10).

Recommended Books:

Several copies of each of the books listed below would be made available, via the library reserve list, for short-term student use. The expectation is that each student will read only one or two of these, with their selections largely depending on their academic background and interests. See section 10 for related discussion.

w. Earth Science focus

D. Archer (2012) "Global Warming: Understanding the Forecast", Wiley.

A. Dessler (2011) "Introduction to Modern Climate Change", Cambridge University Press.

R. B. Alley (2010) "Earth: The Operators' Manual", W.H. Norton & Co.

w. History focus

J. Brooke (2014) "Climate Change and the Course of Global History: A Rough Journey", Cambridge University Press.

G. Parker (2013) "The Global Crisis: war, climate, and catastrophe in the 17th-century", Yale University Press.

S. White (2013) "The Climate of Rebellion in the Early Modern Ottoman Empire", Cambridge University Press.

w. Life Science focus

L. Hannah (2011), "Climate Change Biology", The University of Chicago Press.

w. Economics focus

W. Nordhaus (2013), "The Climate Casino", The University of Chicago Press.

Advanced Reading for Students with a Background in Physical Science:

D. Archer & R. Pierrehumbert (2011) "The Warming Papers", Wiley-Blackwell.

10. *A multidisciplinary TA cohort and the recitation component*

A truly multidisciplinary GEC should provide a multidisciplinary recitation experience. We propose to approach recitations in a rather novel way. Instead of having recitation sections composed of N students led by one TA, we propose to have 3N students led by 3 TAs – one from each discipline. We call this triumvirate a TA 'cohort'. The cohort would provide a multi-disciplinary perspective (though discussions, videos, analysis of news items, etc.) even though the lecturer for that week may have been emphasizing a specific discipline. Obviously this will require the faculty to provide some guidance to the TAs, both before the course starts, and during the course. This will be achieved by assigning some reading to the TAs, and through meetings of the faculty lecturers and the TAs.

As noted in section 9, we plan to ask the students to form an electronic scrapbook of news articles addressing any and all aspects of climate change. Initially, these articles will be discussed by each recitation group and its TA cohort. Each student will be encouraged to read at least one of the books listed in Recommended Reading list. Their election would probably reflect some disciplinary preference (some students already like physical science, others may prefer history, etc.). The idea is that, led by the TA cohort, we want the students to collaborate in multidisciplinary discussions of the materials introduced by the TAs or from the newspaper coverage.

After a few weeks or a month, TAs will lead the students into classifying the new articles into many different categories. By mid-way through the course these stories will be viewed as 'data', and students will choose a specific investigation to be pursued with these data. This investigation will be the subject of each student's poster in the poster session held in the last week. These investigations might be oriented towards physical climate science (e.g. reports on droughts and the connection with fires), biological impacts (e.g. reports of the pole-ward shifts in growing seasons), energy trends, technologies addressing a lower carbon future, and even political science (analyzing science denial, by publication, by location within the USA, etc.). We are confident that each student, STEM-oriented or not, will find some topic of special interest to them. Each student can confer with one or more TAs on his or her investigation.

We hope that the student investigation provides each of them with something approaching a real world scientific investigation (be it physical science, biological science or social science) in that they, and even their instructors, may be uncertain as to the ultimate findings.

11. *Strategies for maintaining focus and course coherence*

The team proposing this multi-disciplinary GEC have met face-to-face several times (typically in subsets) and we have engaged in a great deal of email-based discussion. We anticipate that this level of interaction will continue as the course design is refined.

When the course is actually offered, one of the three faculty lecturers will be assigned the role of coordinator. His or her role will focus on the continuity of language, especially with regards to shared central concepts, as the lecture portion of the course moves from one discipline and the next. The coordinator will normally be the earth scientist, since (1) there are more lectures focusing on this discipline than the others, and (2) because the central logical flow of the course is earth science (physical causes, types of changes, specific predictions for the future climate) -> biological science (impacts on biodiversity, agriculture, disease, etc.) -> historical perspectives on past changes -> energy industry (past, present and future) and the mitigation of climate change. However, there may be special circumstances in which it would be reasonable for the biologist or the historian to play this role.

In the event that the course is successful enough that student demand requires the course to be taught every semester, it is very likely that each discipline's instructor will alternate from semester to semester. This is why we are incorporating at least two faculty members per discipline as we continue to refine the design of the course. Occasionally an entirely new instructor would enter the course. We will encourage new instructors to audit the course in the previous semester. At a minimum the new instructor should examine PowerPoint slides or PDF lecture notes produced by his or her predecessor, and discus them.

12. *Course Assessment*

This course could be evaluated using traditional tools (such as the SEI, and presentation of grade distribution curves, etc.).

But since this course is designed to resolve student GEC requirements in physical science, biological science and history (section 13), we also plan to develop techniques to assess the extent to which the course satisfies expected learning outcomes (ELOs) associated with each special GE category status. These tools would include

(1) a student poll or survey, given at the beginning of course and at the end of course, which is not graded, but seeks to track student knowledge and understanding of climate change, the role of scientific method in climate predictions, the likely range of biological impacts, its social significance, awareness of the role that climate change has played in history, etc. These questions would be formulated as to address general issues pertinent to the ELOs and also to address more specific issues of interest to the teaching team. The survey or poll questions would not change, and therefore the changes in the answers would characterize the impact of the course on its students.

(2) embedding of special questions into the midterm and final exam that specifically test if the course is achieving ELOs, and parsing the results into a special analysis.

(3) Polling the TAs to determine their perspective on the achievement of the ELOs, the special contributions of mutlidisciplinarity, and to collect their suggestions for improvement in the course as a whole, and the recitations in particular.

We would also invite any interested parties to attend the end-of-semester student poster session, both to assess the quality of these presentations, and to talk to the students about their impressions of the course.

We are open to additional suggestions.

13. *Expected Learning Outcomes (ELOs)*

Here we discuss how our course addresses GE expected learning outcomes (ELOs) in general terms, and present a Lecture Topic – ELO coincidence matrix for each class of GEC category that we wish to be granted.

13.1 Physical and Life Science ELOs

The published ELOs for Physical Science and Biological Science are identical. They are:

S1. Students understand the basic facts, principles, theories and methods of modern science.
S2. Students understand key events in the development of science and recognize that science is an evolving body of knowledge.
S3. Students describe the inter-dependence of scientific and technological developments.
S4. Students recognize social and philosophical implications of scientific discoveries and understand the potential of science and technology to address problems of the contemporary world.

13.2 Historical Studies ELOs

The published ELOs for historical study are:

H1. Students construct an integrated perspective on history and the factors that shape human activity.
H2. Students describe and analyze the origins and nature of contemporary issues.
H3. Students speak and write critically about primary and secondary historical sources by examining diverse interpretations of past events and ideas in their historical contexts.

13.3 Lecture Topic – ELO Coincidence Matrix and Illustrative Notes

The following page presents the Lecture Topic – ELO Coincidence Matrix which maps lecture topics onto specific ELOs. In some cases we provide some illustrative footnotes tied to the elements of this matrix which explain the nature of the coincidence of lecture theme and ELO.

LECTURE THEMES	Science ELOs (Section 13.1)				History ELOs (Section 13.2)		
THE CLIMATE SYSTEM	**S1**	**S2**	**S3**	**S4**	**H1**	**H2**	**H3**
Climate versus Weather	• E1	•					
Solar radiation and the Greenhouse Effect	•	• E2					
Atmospheric and oceanic circulation	•	•					
The water cycle	•	•					
The carbon cycle	•	•					
Climate, biology and agriculture	• B1		• B1				
Climate, culture and economics	• B1						
CO2 AND CLIMATE CHANGE							
CO2 – the Keeling curve & the ice core record	•	•		• E3			
Intensification of the Greenhouse Effect	• E4	•		•			
Ocean acidification	•	•		•			
Global Warming	•	•		•			
Intensification of the water cycle	•	•		•			
Intensification of severe weather	•	•		•			
Ice loss and related loss of water resources	•	•		•			
Sea level rise	•	•	• E5	•			
BIOLOGICAL RESPONSES TO CLIMATE CHANGE							
Biodiversity – Terrestrial and Marine	•	•	• B2	•			
Agriculture	• B1	• B1	• B1	• B1			
Drought, fire and landscape	• B3			• B3			
Plant and Animal Migration	•						
Disease and Disease Vectors	•	• B4	• B5	• B6			
HISTORICAL EXPERIENCES OF CLIMATE CHANGE							
Collapses of ancient cultures					• H1		• H2
Vulnerability and crisis in traditional societies					• H3	• H4	
Climate and conflict					•	•	
Climate and culture					•		• H5
Adaptation and resilience through history						•	
Climate and weather in the modern age			•			•	•
Effects on modern human infrastructure						• H6	
The Socio-Economics of Managing Risk						•	
MITIGATION AND ADAPTION							
The energy industry and its trends							
Fossil Fuels & Nuclear Energy			• E6	•			
Renewable Energy			• E6	•			
Energy Efficiency			• E6	•			
Transition to a low carbon future							
Is it possible to do this fast enough?			•	•			
Historical transitions of a similar character							
Science and politics: recent global issues						•	
Environmental problems & engineered solutions			•	•			
Past energy transitions & other tech transitions	•		•	•	•	•	•
Economic complexities and trade-offs				•	•	•	•
SUMMARY & DISCUSSION	•	•	•	•	•	•	•

NOTES Specific rationales for assigning a few of the coincidence 'bullets' above

E1 Failing to understand the distinction between weather and climate leads to common but scientifically erroneous positions

E2 We will describe the development and refinement of the greenhouse concept since J. Fourier (1820s) onwards. Scientific understanding of the Greenhouse Effect (and the enhanced GE) built slowly but inexorably.

E3 The iconic Keeling curve, and the notion of CO2 doubling, will be used to connect scientific, technological, economic and social themes

E4 This topic requires us to integrate facts (e.g. rising C02), properties (e.g.radiative), theories (e.g. of convection), and manage uncertainties (e.g. cloud feedback)

E5 We will describe the complex interplay between science and technology using the history of sea level measurement and analysis, from tide gauges to altimetry & the GRACE gravity mission

E6 This group of lectures demonstrate that science and engineering can build modern economies and lifestyles, simultaneously causing major problems for humanity, but also establish the technical means to solve or adapt to these problems

B1 We will describe the bio/genetic history of agriculture from original domestication of wild species, to conventional breeding ('artificial selection'), to Genetically Modified Organisms and the public's apprehension of GMOs.

B2 We will describe how technology once limited the discovery and description of biodiversity (e.g. global travel, discovery of "genetic species" not otherwise recognizable) and now how fossil-fuel intensive technology is threatening biodiversity.

B3 We will discuss the "natural" occurrence of these kinds of events and the extent to which they are increasing in severity and frequency; this addresses a common misconception of "natural" events

B4 The history of our understanding of disease from a mystic perspective to a scientific one provides a time-line of the Scientific Revolution; we have a student-discovery exercise examining this history

B5 We will discuss the discovery and theoretical explanations for antibiotic resistence here.

B6 Having discussed the inevitability of antibiotic resistance (B5), we will discuss Ebola, the climate and habitat influence on the spread of Ebola, and the limited usefulness of many anti-Ebola drugs due to the development of resistance .

H1 This lesson combines archaeological and written records from several regions of the world to explore how humans faced significant environmental challenges and political and social change.

H2 This lesson considers the reasons for public interest in ancient “collapses” and their relevance to contemporary climate change impacts

H3 This lesson analyzes the impacts of climate variability and change on human agriculture, food systems, and health and their influence on economics and politics.

H4 This lesson considers regional vulnerability and resilience to climate change in relation to long-term development and economic and political equality

H5 This lesson incorporates primary sources (including historical paintings) for interpretation of past climate impacts on culture.

H6 This lesson examines the climate change vulnerabilities created by decisions of planning and infrastructure over the past century