From Environmental Problem Awareness to Earth System Science: Using Curriculum Alignment to Promote Deep Learning in Sustainability Science

LATHE 2 Course Project Report

Kim Nicholas
Lund University Centre for Sustainability Studies (LUCSUS)
Kimberly.nicholas.academic@gmail.com

21 May 2013

1 Abstract

This paper reviews the present teaching situation for the introductory Environmental Problem Awareness course in the Lund University Master's Programme in Environmental Studies and Sustainability Science (LUMES), and proposes a redesign to enhance deep student learning based on the principles of curriculum alignment. The current transition to a new curriculum within LUMES presents an opportunity to implement revisions to the course learning outcomes, teaching and learning activities, and assessment tasks to better align them with the goals of the course and provide a natural science foundation that has been well-integrated with the LUMES program. In particular, the proposed revisions focus on learning and applying skills in quantitative data analysis and visualization and experimental design to the subject matter of the Planetary Boundaries on both a global and local level. This design is intended to increase student motivation, transdisciplinary experience, and interpersonal skills in the context of sustainability science education. Feedback from colleagues has been incorporated throughout.

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2 Introduction: Present course design and teaching situation

I am a lecturer in the Lund University International Master's Programme in Environmental Studies and Sustainability Science (LUMES), a program established in 1997 with an interdisciplinary, international approach to global environmental sustainability challenges. We have approximately 40 MSc students every year, who go through all the courses in the program together as a "batch," which develops a strong sense of identity and cohesion. The students come from a diverse range of backgrounds, both geographically (historically, more than 80% of our students are international, often with more than 20 countries represented in each batch) and in terms of subject training, with academic backgrounds ranging from engineering to anthropology to history to ecology. This diversity is a hallmark of the program, but also presents challenges in finding the right level of course material that is accessible for those with no background, but still engaging for those with extensive experience in a discipline or topic.

My department is currently developing a new curriculum for our MSc program based on the Five Core Competencies in sustainability science proposed by Weik et al. (2011): namely strategic, systems thinking, anticipatory, normative, and interpersonal competence. I have participated in the curriculum redesign team, and I am the course responsible for the first course in the program, Earth Systems Science, which will kick off the beginning of the new program in August 2013. The first semester of the program consists of three ten-credit courses: Earth Systems Science, Social Theory and Sustainability, and Sustainability Science. I am collaborating with the other two teachers in this semester to attempt to align our courses to complement each other. The vision is that the ESS course will provide the natural science basis, followed by Social Theory and Sustainability, which focus on human and social dimensions of sustainability and the philosophical paradigms underlying them, then Sustainability Science, which integrates theory and practice in addressing real-world sustainability challenges using theoretical frameworks such as resilience and multi-level analysis.

Previously, the first course in the program was a 5-week, 7.5 ETC credit course called Environmental Problem Awareness (EPA). EPA was structured around a framework developed by the previous instructor, the "Seven Challenges to Sustainability," which were climate change, biodiversity loss and deforestation, water scarcity, ill health, overfishing, food insecurity, and desertification. These were conceived as natural science "discoveries" that had now become the domain of social or sustainability science to deal with (A. Jerneck, pers. comm). The first year that I taught EPA, in 2011, I retained this structure of the Seven Challenges. In many ways it worked well in providing an overview of environmental issues, many of which are explored more deeply later in the program curriculum. However, while teaching the course, I found this structure to be somewhat problematic because the challenges were not on the same level conceptually (for example, "climate change" is a biophysical phenomenon, which we are trying to minimize for sustainability, while health and food security are normative human conditions, which should be maximized for sustainability. A deciding point for me was when one of my former students came in to my office to ask what the origin of the Seven Challenges was, so he could cite it in his MSc thesis, and we realized that, while a paper referenced four of the seven challenges as organizing principles for sustainability research (Jerneck et al., 2010), there was no peer-reviewed reference for the Seven Challenges, although many of our students were using in their subsequent papers and research.

Based on this experience, I decided to seek a substantive theme that was more firmly grounded in the academic literature and in international development practice, where most of our students will go on to after graduation. With this in mind, in 2012, I chose to structure the EPA course content around the "Nine Planetary Boundaries" proposed by Rockström et al. (2009; Figure 1). This has the advantage that all the Boundaries are biophysical elements of the Earth system for which sustainable range limits have been established (for example, the historical rate of species extinction, compared with the present rate nearly 1000 times higher), so they are easy to define and measure. While this framework is also subject to criticism, it is now being widely used both in academia (with over 900 peer-reviewed citations in less than 4 years), as well as in sustainable development practice and policy. We plan to address the criticisms of the Planetary Boundary approach in the Sustainability Science class through reading and discussion of critical responses, including that from an Oxfam International Discussion Paper (Raworth, 2012).

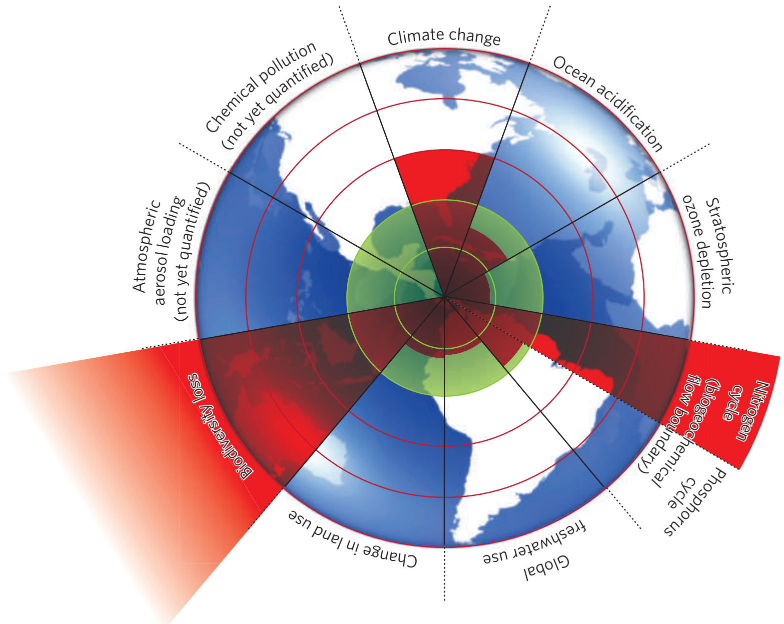

Figure 1 | **Beyond the boundary.** The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded.

Figure 1. Planetary boundaries, the conceptual framework for the Earth Systems Science course. *Source*: Rockström et al., 2009.

For 2013, the course will be taught in a new format for the first time. Now called Earth Systems Science (ESS), the course goal has been modified to focus on establishing the natural science foundation for global sustainability issues through the lens of the Planetary Boundaries; while human contributions to and solutions to these issues will be touched on, the focus will be on natural science, with subsequent courses focusing more on the social and economic dimensions of these issues. ESS has been expanded by 2 weeks to become a 7-week, 10-ETC course. The additional two weeks are designed to allow coverage of quantitative methodology and statistics, a subject I previously taught in a short (ca. 2 week) module on Quantitative Methods within a 10-week Methods course in the spring. As part of the curriculum redesign, we have eliminated the Methods course as a stand-alone course, and are aiming to integrate the tools and approaches formerly taught in isolation there with relevant subject matter in the rest of the courses, so that the skills can be immediately applied in a relevant way. I would like to further use this opportunity to better link the course material with student's everyday experience to make the material more relevant and motivating (Andresen et al., 2000), in addition to the focus on the rather abstract global level.

The goal of this course project was to use constructive alignment to design a course that effectively provides opportunities for student learning within the established theoretical course structure I have envisioned. Constructive alignment is the process of ensuring that course learning goals, activities, and assessment tasks are coordinated to produce the intended outcomes for

student learning (Biggs and Tang, 2011). Critically, this approach places student learning (rather than teacher activities) at the center of the class, and ensures that the course focuses on essential skills, content, and mastery levels expected of the students. These should be made clear at the outset, and can be used to check the importance of various course activities. This document both outlines the plan and rationale for the course, as well as including the process of the development of my thinking on these topics as part of my own scholarly reflection. It is my intention that this document can serve as a guide to assist future course development in LUMES, as well as improve the quality and level of reflectivity of my own teaching, and most importantly of student learning in my class.

3 Intended Learning Outcomes

3.1 Literature Review

Biggs and Tang (2011) give a clear example of constructive alignment from real life. In teaching a child to tie her shoe, the intended learning outcome is that the child is able to tie her shoe independently and with proficiency so that the shoe stays on her foot. The activity used to achieve this outcome is lots of practice tying her shoe (not listening to long instructions on, or reflections about, shoe-tying, or watching a slideshow about how other people have tied their shoes). The assessment is based on whether or not she can tie her shoe.

This simple example illustrates many important points about intended learning outcomes, and about the process of constructive alignment. First, learning outcomes represent an absolute rather than a relative bar. To pass the class, or to be considered a proficient shoe-tier, the student must be able to demonstrate a sufficient level of proficiency. The important thing is not how well a student performs relative to other students, but **how well they perform relative to the standards established by the learning outcomes.** Second, learning outcomes must contain a verb that specifies the activity that the student is expected to perform, and this skill must be practiced through the design of thoughtful teaching and learning activities that allow the development of skill and the opportunity for self-reflection on learning, as well as teacher and peer feedback, some of the most important elements for promoting student learning (Biggs and Tang, 2011). Finally, it is important to “start with the end in mind,” knowing what it is that you want students to be able to do as a result of your course (that is, what is the learning that you want to take place), so that you can design the class to achieve this.

Biggs and Tang (2011: p. 125) state that learning objectives should be formulated to stipulate the verb at the appropriate level of understanding, the topic content that the verb addresses, and the context and level of quality in how the verb is performed. In other words, we should specify what it is that the student should be able to do after the learning process, what subject it is that we want them to apply their action, and the level of mastery that is demonstrated in performing the skill in relation to the content. To ensure that each of the three elements are present, we learned in the LATHE course that it is helpful to highlight them to allow quick visual inspection. Here I have highlighted verbs in yellow, substance in green, and quality level in blue. For example, an example from the LATHE class stated that an ILO for a course on economic history might state that students should summarize and analyze academic texts about economic history in a comparative, evaluating manner.

To support curricular alignment, it is helpful to select the active verb from a taxonomy of learning verbs, such as Bloom's revised taxonomy (Krathwohl, 2002), or the structure of the observed learning outcome (SOLO) taxonomy (Hattie and Purdie, 1998). These are classification systems that go from more simple, memorization-focused skills, such as "recall or name", to more sophisticated, multistructural skills, such as "apply, compare, and analyze", eventually culminating in extended abstract skills such as "hypothesize, synthesize, or design." This allows designing ILOs to exhibit progression and ensure the intended outcomes are at an appropriate level of mastery. While there is room for developing many skills, at the master's level, the focus should be on higher-order skills that are linked with the higher level of understanding expected at this stage, where students have moved from multistructural to relational and extended abstract abilities (Biggs and Tang, p. 125), and are able to apply functioning rather than declarative knowledge (Biggs and Tang, p. 81-83). For more information on these two taxonomies and a comparison between them, see Appendix 1.

3.2 Present and Revised Intended Learning Outcomes

In revising the ILOs, I started with the ILOs for the course that are currently on the books (and have been approved by the faculty for teaching in Fall 2013, so these will be the ILOs that I use for the next time I teach the course; the new ILOs will be submitted to the faculty in a later process for review and adoption). As shown below in Table 1, the level of mastery expected was missing from all of these ILOs (no blue highlight in second column), and in many cases the subject for application was also missing (green highlight in second column).

I modified these for a first draft of revised ILOs (Column 3 in Table 1). I received feedback from my peers in the LATHE course that they were too long and detailed, and combined too many different aspects. I therefore condensed them, and made separate ILOs for conceptually distinct ideas, ending up with six instead of four ILOs. I also modified the second draft ILOs to reference Planetary Boundaries (the new conceptual framework) rather than Sustainability Challenges (the old conceptual framework).

Table 1. Progression of development of Intended learning outcomes (ILOs) for the Earth Systems Science course. The present version of the ILOs is in the third column on the right. Each ILO should contain each of the following elements: an action verb (highlighted in yellow; a substance that the verb is applied to (highlighted in green highlight); and the level of mastery and context expected (blue highlight).

Current Course ILOs (approved by faculty in 2011)	First Draft Revised ILOs (from LATHE course)	Second Draft Revised ILOs (incorporating feedback)
a capacity to explain the structure and function of the Earth system, including its physical, chemical, and biological subsystems, as well as human drivers and trends, and how these relate to sustainability challenges such as climate change, land use change, biodiversity loss, and global freshwater use;	Describe in words and draw in pictures, and explain the relationships between, the physical, chemical, and biological aspects of the Earth System, as they relate to global sustainability challenges such as climate change, land use change, biodiversity loss, and global freshwater use, and the human drivers and trends contributing to these challenges, and translate these challenges to the local level using concrete problems, in a comparative, evaluating manner.	1. Describe in words and symbolize in pictures, and explain the relationships between, key physical, chemical, and biological aspects of the Earth System, as they relate to the Planetary Boundaries, in a comparative, evaluating manner.
a capacity to employ the scientific research process, including problem formulation, analytical reasoning, experimental design, data collection and analysis, and presentation orally and in writing;	Employ the scientific research process, including problem formulation and hypothesis development, analytical reasoning, experimental design, data collection and analysis, and presentation orally and in writing, to address sustainability challenges in a sophisticated, data-driven manner.	2. Demonstrate mastery of the scientific research process, and use it to hypothesize about ecological conditions in a field experiment in a sophisticated, data-driven manner.

the ability to use appropriate tools and methods to visually and statistically represent, analyze, and interpret quantitative data related to sustainability challenges, and	Select and use appropriate tools and methods to visually and statistically represent, analyze, and interpret quantitative data related to sustainability challenges with sophistication, creativity, and clarity, and fluidly convert between words and images in analyzing and presenting such data.	3. Select and use appropriate tools and methods to visually and statistically represent, analyze, and interpret quantitative data related to Planetary Boundaries with sophistication, creativity, and clarity.
skills in academic writing, the independent use of academic libraries and resources, including bibliographic databases, to critically evaluate, process, and compile information as needed, and skills in leadership, communication, and effective group work in a multi-cultural setting.	Demonstrate skills in academic writing, including the independent use of academic libraries and resources, including bibliographic databases, to critically evaluate, process, and compile information as needed in support of writing well-researched and properly referenced academic texts on sustainability challenges, and skills in leadership, communication, and effective group work in a multi-cultural setting, to a high degree of proficiency.	4. Demonstrate skills in academic writing, including the independent use of academic libraries and resources, to produce well-researched, clearly written, and properly referenced academic texts on an ecological field experiment, linking it with larger Planetary Boundaries, in a professional academic manner.
		5. Apply skills in leadership, communication, and effective group work in a multi-cultural setting, to contribute to interpersonal competencies in sustainability science, to a high degree of proficiency.
		6. Extend the global Planetary Boundaries concept to a local level, and analyze and evaluate local solutions to related challenges, in a professional manner.

Further, I analyzed the active verbs used in terms of their learning taxonomy levels (Table 2). There were no verbs at the most basic Level 1, which is appropriate for a MSc-level class. About half the verbs are Level 2, a third are Level 3, and two are Level 4. Two verbs currently in the ILOs, "select" and "represent," were not presen in either taxonomy; in subsequent revisions as I prepare the course, I may try to change this to use standardized verbs, and to consider using a logical progression i sophistication between ILO's, with each ILO focused within one level to facilitate assessment.

Table 2. Current status of active learning verbs used in course intended learning outcomes (columns 1-6 correspond to the 6 ILOs), sorted by increasing level of sophistication. The Level comes from the SOLO taxonomy where available, out of a possible maximum of 4. The two verbs with * were present in Bloom's but not SOL taxonomy; these were converted to the relative SOLO scale (e.g., from the highest level of 6 in Bloom's became a level 4 in SOLO). See Appendix 1 for more information.

		ILO					
Verb	SOLO Level	1	2	3	4	5	6
describe	2	x					
explain	2	x					
symbolize	2	x					
interpret	2			x			
extend	2						x
Use*	2		x	x			
apply	3					x	
evaluate	3						x
demonstrate	3		x		x		
analyze	3			x			x
hypothesize	4		x				
Produce*	4				x		
select	Not listed			x			
represent	Not listed			x			

4 Teaching and Learning Activities

4.1 Literature Review

Teaching and learning activities refer to the activities designed to produce the student learning specified in the intended learning outcomes, and may include everything from in-class activities, lecture, group work, readings, and other activities inside and outside of class. They are what the course calendar is filled with, and should be designed to support the intended learning outcomes.

Students may take either a surface approach to learning, where they take shortcuts or put in the least amount of effort possible to pass, or a deep approach, where they engage deeply and creatively with the learning activity and the subject, treating the learning activity as a pleasurable challenge from which they derive long-lasting skills (Biggs and Tang 2011, Chapter 2). Surface learning is promoted by excessive time pressure, classroom atmospheres that promote anxiety, and assessment activities that focus on independent facts rather than conceptual structures and their linkages. Deep learning, on the other hand, is encouraged by student motivation and determination, sufficient background knowledge, and abstract thinking skills (Biggs and Tang, 2011, pp. 26-27). Further, deep learning is enhanced by teaching in a way that builds on student's existing knowledge and addresses misconceptions, explicitly brings out the structure of a subject and assessing on this structure, actively engaging students rather than presenting information, and emphasizing depth of learning rather than breadth of coverage (Biggs and Tang, 2011, pp. 26-27). Obviously, focusing on deep learning is preferable, particularly at the MSc level, and teaching and learning activities should be designed to do this.

Unfortunately, the most common teaching activity, the lecture, has been convincingly demonstrated to be an ineffectual learning activity for students under most circumstances, for two main reasons. First, lectures usually involves only passive learning by students (listening or perhaps taking notes), without the opportunity to practice the skills they are supposed to be gaining in the class (e.g., the ability to explain, synthesize, etc.) (Biggs and Tang, 2011). Second, attention span declines markedly after about 15 minutes without a change in activity, so that effective learning is much lower at the end of lecture than the beginning (Bligh, 1972). Providing time for reflection and review at the end of the lecture can dramatically increase student learning (Bligh, 1972), as can a change in activity, such as buzz groups or even a stretch break.

4.2 Present Teaching and Learning Activities

The current structure of the Environmental Problem Awareness course focuses around lectures, approximately one three-hour lecture per Planetary Boundary (with some topics combined into one lecture), plus two lectures on Academic Writing. Lectures include some time for discussion or in-class activities, such as drawing on shared whiteboards and presenting to the class. There are also introductory lectures on using the library resources at Lund University.

The course presently includes a heavy focus on writing, to get students up to speed with the level and frequency of writing expected from them in the MSc program. Presently the course includes two writing assignments. The first is a short (1200 word) Pre-Course Assignment, a popular science description of one of four environmental issues in Sweden, which is due before the students arrive in Lund. They are given resources and links to find information about Sweden written in English, and are not expected to use peer-reviewed sources, as they do not yet have library access. Shortly after arrival in Lund, the students meet in small groups with a tutor to get feedback on their papers (which are not graded) from both a tutor and one of their peers. This is an opportunity to assess their level of English expression and direct students who need help to resources at the University. They then prepare a joint group presentation for the class, informing them about this environmental issue in Sweden, which is then used as a basis to help inform their group research project.

The second paper is based on the group research project, from an ecological field experiment that the students design and conduct on the field excursion to a nature center in Breanäs. The students collect and analyze data in the field, then have time back in Lund to write a group paper, which is presented in a final oral presentation to the class.

Student time availability needs to be taken into consideration in the course design. As the first course in the program, there is a lot of logistical coordination to provide the students (e.g., getting them oriented to Lund University, to studying at the MSc level, and to life in a new country). Approximately 80% of our students are international, and many have just arrived in Sweden for the first time (some coming with their suitcases straight from the airport on the first day of class!) and are dealing with culture shock and practical necessities of living in a new country simultaneously with a demanding course load.

4.3 Planned Teaching and Learning Activities in Earth Systems Science

I believed that the current structure is too heavily lecture-focused, with not enough opportunity for active student engagement with course material and deep learning. However, I have received feedback from both students and colleagues that they value the current lecture structure and find it effective. Research shows that lectures can be an effective form for student learning if lecturers present the latest research, organized in a clearly articulated structure that is explicitly presented to students, to help students think more like experts (Biggs and Tang, 2011). Therefore I will maintain some lectures while trying to incorporate more active learning opportunities as well.

Additionally, I would like to include more training in research design and ecological measurement through adding field exercises (last year was the first time this had been done, thanks to the initiative of a former student who volunteered to organize a very successful lab activity), and in problem-based learning based in a local context. Finally, due to the changed structure of the course, I need to incorporate training in statistical analysis and data visualization and interpretation in this course (previously it was a separate module). I have included activities for instruction in study skills at the graduate level, shown to be an effective strategy for promoting student learning (Hattie, 2009).

I will now present a brief overview of the planned teaching and learning activities, broken down by intended learning outcome; please see Table 3 for a summary.

4.3.1 TLAs for ILO 1: Natural science knowledge

I plan to retain some lectures to convey structural frameworks for interpreting the natural science knowledge taught in this course. However, I will limit lecture time and include regular breaks for activities and buzz sessions to keep interest levels high. I will also design group activities in-class; for example, assigning groups different aspects of the carbon cycle to study and explain to the class, who then have to put it all together to see what happens with changes to radiative forcing for climate change. I have discussed with colleagues who teach the following two courses in the first term, and we have agreed to develop a case study on climate change that will carry throughout the first term, where it can be examined from different perspectives. We plan to select a current article from the science writer George Mumbias in The Guardian, which the students will analyze in my class from a natural science perspective, and then revisit from social science and sustainability science perspectives later in the term.

4.3.2 TLAs for ILO 2: Scientific research process

This ILO will be achieved through in-class exercises on developing hypotheses and research questions, which are then applied in the group research project. In collaboration with several colleagues, we will develop and present field labs at Breanäs where we give students practice in designing experiments appropriate for statistical analysis, making choices about replication and sampling (systematic, random, quadrat, transect, etc.), and using tools and making ecological measurements such as using maps and compasses, Google Earth, clinometers to measure tree height, identifying flora and fauna species in the field, and making measurements and calculations of species diversity, density, and frequency. There will be groups organized around four of the Planetary Boundaries: Biodiversity, land use change, water, and nitrogen and phosphorous. Groups will then design a research project to be carried out in Lund, using suggested locations that will familiarize them with the local environment. After collecting the data together, the groups will split in pairs to analyze the data using the statistical programming language R and incorporate scientific literature to interpret the data and put it in context. Groups will then participate in a peer-review session where they read and comment on each other's papers and reflect on how they have started with the same data and may have reached different conclusions. Finally, I plan to ask researchers from LUCSUS to give short presentations to the class on their current research, focusing on the research design process, to highlight research in action and encourage students to conduct research that builds on existing efforts in our department (an initial list of possible speakers is in Table 4).

4.3.3 TLAs for ILO 3: Statistics, visualization, and quantitative data

We will have a one-day introduction to the conceptual modeling software Stella, run by two PhD students in our department. This will give students a chance to practice a way to visualize complex environmental issues and their interconnections. To introduce visual data literacy and give skills in taking a data-centered approach to reading the primary literature, I plan to follow a learning program called Figure Facts, a worksheet and skills training for interpreting data that has been shown to increase data interpretation skills and received overwhelmingly positive student reviews from undergraduates in neuroscience (Round and Campbell, 2013). We will use this approach to read and discuss one short peer-reviewed article for each Planetary Boundary. I will deliberately limit the amount of reading, and use the reading in activities in class, to encourage students to do the reading.

I will also continue developing the "flipped classroom" model (e.g., https://www.khanacademy.org/, Tucker, 2012) that I began using this year in teaching Quantitative Methods, where students are assigned readings and video lectures on statistical topics to review at home, and perform exercises in class to apply these topics. This received very high student reviews, and I was very happy with the deep learning demonstrated on the course project in the class this year. However, I need to work to develop better in-class activities to use and apply statistics to real-world problems, and offer students experience in selecting, performing and interpreting statistical tests. We will also use the in-class tutorials I have modified from a colleague at Michigan State to teach the powerful statistical programing language R. I am making arrangements to hire two teaching assistants (students from last year's class who excelled in this program) to help with this portion of the class, as last year I was the only instructor for a room full of 35 people moving through the exercise at different paces.

4.3.4 TLAs for ILO 4: Academic writing

Academic writing is a core skill in every course of the LUMES program, culminating in the thesis. In ESS, I aim to set the foundation for successful academic writing by arranging an introduction to the library resources at Lund University, held by our partner reference librarian at the GeoLibrary, Britta Smångs. The students receive feedback on the Pre-Course assignment; I will consider whether to have them revise the papers to promote progression in writing, or possibly incorporate them into the course paper.

A consistent problem that our students face is in distinguishing peer-reviewed from other sources, and in properly referencing literature in writing, so I will design activities to ensure this is met. I will expand this year by explicitly focusing on graduate-level study skills, such as reading academic articles and time management, learning style inventories, and conducting more focused exercises on writing, inspired by the Writing Revolution model being used to teach critical thinking through writing in American secondary and higher education, and the work of Joseph Williams.

4.3.5 TLAs for ILO 5: Interpersonal competencies

We will develop skills in leadership and effective group work through introducing a groupwork contract (modified from a version currently used in the Lund University program in visual culture, where it is very effectively used) that can be used as a basis for all future groupwork in the LUMES program to establish effective, fair, and positive norms for collaboration in the program and beyond. The students will need to submit a copy of their contract with group assignments to demonstrate that they discussed issues such as workload, time management, roles, and responsibilities ahead of time, and managed them effectively, skills we are trying to promote. We will also introduce the Wiek et al. (2011) article early on in the course, which outlines competencies for sustainability science education, to show students the rationale for the curriculum design and encourage them to be actively involved in and reflective on their own learning. We will use the time at Breanäs to conduct communication, teamwork, and leadership activities, in collaboration with LUMES students with experience in these tasks through training programs such as Art of Hosting and International Exchange. Finally, we will begin training on public speaking and presenting through readings and information on giving presentations, and through having peers offer feedback on each other's presentations.

4.3.6 TLAs for ILO 6: Analyze and evaluate local solutions

This is a newly added ILO that aims to increase student motivation and deep learning by promoting transdisciplinary involvement with real-world problems and local stakeholders. This is begun with the Pre-Course assignment focusing on environmental issues in Sweden to build up student knowledge of the local context before arrival, and continued with short student presentations in class on current topics from the local news of relevance to sustainability. I hope to invite guest speakers from local government, community organizations to inform our students about the sustainability efforts happening in Sweden, pressing problems, as well as innovative approaches being taken to address them (an initial list of possible contacts is in Table 4). Finally, the course research project being focused on a local environmental issue for data analysis (and possible communication to real stakeholders) will allow students to apply their skills in a real-world context. This can be supported by the Earth Systems Analytical Framework, which I developed with colleagues at Stanford University for understanding and developing and implementing solutions to environmental issues.

Table 3. Alignment between Intended Learning Outcomes (ILOs) and Teaching and Learning Activities (TLAs).

Condensed ILO (see Table 2 for full list)	Teaching and Learning Activities
1. physical, chemical, and biological aspects of Planetary Boundaries	Assess pre-knowledge and identify misconceptions
	Lectures (including student-led and jigsaw format)
	Readings
	In-class activities
	Climate change case study with Barry and Turaj
2. Scientific research process	Ecological field labs
	Readings
	Hypothesis development exercise
	Research project
	Guest presentations from LUCSUS researchers
3. visually and statistically represent, analyze, and interpret quantitative data	R tutorials
	Systems Thinking CLD day, Intro to Stella
	Readings- UN Guide to Using Data; stats
	Flipped classroom- videos on statistics outside of class, short lectures
	Figure Facts exercise
4. Demonstrate skills in academic writing	Library workshop
	Pre-Course Assignment
	Graduate study skills workshop; learning styles inventory
	Analysis of academic texts
	Exercises from Writing Revolution, in-class demonstration of live writing process
	Peer review process and feedback
	Citation workshop
5. Leadership, communication, and effective group work	Groupwork contract
	Wiek et al. 2011 discussion
	Teambuilding and group dynamics exercises at Breanäs
	Peer assessment of presentations
	How to Talk reading and lecture
6. analyze and evaluate local solutions	Pre-Course Assignment
	Course project
	Guest speakers and local field trips
	Swedes read and present local news
	Earth Systems analytical framework

Table 4. Local contacts related to some of the core Planetary Boundaries, to investigate further for designing guest lectures.

Planetary Boundary topic	Lund contact	LUCSUS researchers
1. Nitrogen and phosphorous	• Kjällby water treatment plant (Ann goes there for water course) • Xavi? (Kim)	Ann Elina
2. Water	• Anna Karin Vikstrom, Sydvatten (Bodil) • Vattenhallen water purification display • Lab topic: Managing stormwater runoff in Lund	Vasna Mine Sara
3. Biodiversity	• St. Hans Parken (Bodil) • Botaniska tradgard • Henrik Smith • Grönare Lund? • Stadstradgardsmester • Park och Natur	Torsten Elsa Kim
4. Land Use Change	• Brunshallen planning (Tobias?) • Radish • LUCSUS garden • Brunshallen garden • Lab: management of prime topsoil moved for building; compost system for kolonis	Sara Lennart Christine Molly
5. Climate change	• Lunds Kommun speaker	Kim

5 Assessment Tasks

5.1 Literature Review

In constructive alignment, assessment tasks are designed as a source of evidence of a student's achievement of the intended learning outcomes (Biggs and Tang, 2011). Further, the time required to prepare for and complete the assessment tasks (both by students and by teachers) should reflect the importance of the ILO (Biggs and Tang, 2011, p. 225). Given students' tendency to focus heavily on assessment and "learn for the test," it is important to design assessment activities that align with the intended learning outcomes of the course, so that students' focus on assessment results in their deep engagement with the material and achieving the intended learning outcomes (Biggs and Tang, 2011, p. 198).

While exams may be successfully used to ensure the breadth and accuracy of student knowledge, and the time pressure required to study for and take an exam can provide positive motivation for student review and synthesis, leading to deep learning (Biggs and Tang, Ch. 11), exams also have shortcomings as assessment techniques. In particular, the time constraint of performing under an exam is not well-aligned, unless the intended learning outcome is itself time-constrained, and the exam is more likely to promote surface rather than deep learning compared with an assignment (Biggs and Tang, 2011). A poorly designed exam can lead to memorization and other surface learning strategies, and outcomes where "Nobody is telling anything new to anybody," (Biggs and Tang, 2011, p. 227), which are poor examples of learning.

According to a meta-analysis of over 800 meta-analyses, involving over 50,000 studies and 250 million students, the characteristic that produced the most positive outcomes on student learning (nearly 50% larger effect than the next best characteristic, and more than three times as effective as the average strategy tested) was when students self-report grades (Hattie, 2009). It appears that this feature gets students to become more reflective and therefore deeper learners, in effect teaching them how to learn by encouraging them to better monitor, evaluate, and assess themselves, looking for evidence of how they are doing, keeping an eye out for errors and looking for ways to work more effectively (Biggs and Tang, 2011). Therefore, an important part of my revised strategy will be incorporating student self-reporting grades.

The second most effective characteristic, which was more than twice as effective as the average, was when students provided formative evaluation to lecturers; that is, they gave feedback on the course and their learning, and are able to offer suggestions for improvement that can be incorporated in the course while it is running (Hattie, 2009). I can say from my own experience that I had a professor who did this when I was an MSc student, and it greatly impressed me. I have since incorporated it into all my classes, and find it to be a highly effective activity. It nearly always happens that students have a very good idea for improving the course, as well as small suggestions that are easy to accommodate and facilitate the course. Finally, providing feedback to students is one of the most important activities to promote student learning (Hattie, 2009).

I currently follow many of the recommendations from the literature for grading to ensure fairness and accuracy- namely, to grade blind in order to avoid the "halo effect" where good students are given the benefit of the doubt, assessing across questions (grading all examples of question 1 together, then question 2, across exams) rather than across students (reading through an exam from start to finish) to maximize independence, reshuffling the order of exams graded between questions to prevent systematic order effects, and asking a colleague to comment on the exam wording before administering it to avoid ambiguity (Biggs and Tang, 2011, p. 232).

One concern is the fairness of grading the essay assignment in the exam, which also applies to grading other written assignments in the program. Research has shown that grading for papers is extremely inconsistent between judges (in many cases, with the same paper being given a grade from bare pass to nearly top marks), due to different criteria used in grading between judges (Biggs and Tang, 2011, p. 231). Four families of criteria for grading writing were identified by Diederich (1974; Table 5), which are recommended to be clearly and collectively articulated and agreed upon in a set of rubrics (grading guidelines specifying what level of each criteria is expected for what grade).

Table 5. Criteria identified for assessing written assignments by Diederich (1974). For maximum fairness between students within a class, and between teachers within the program, criteria should be established for these that are clearly apparent to the students and consistently applied in establishing grades.

Ideas	Originality
	Relevance
	Logic
Skills	Mechanics of writing
	Spelling
	Punctuation
	Grammar
Organization	Format
	Presentation
	Literature review
Personal style	Flair

5.2 Current Assessment Tasks

Presently, half of student's grades are based on a three-hour, in-class final exam, which focuses on testing higher-level skills such as data interpretation and analysis, linking and synthesizing ideas, and writing a short essay (Table 6). This is one of the only exams given in the LUMES program (most of the rest of the courses base assessment on individual or group papers or presentations). I have been happy with the exam as a way of testing higher-order thinking and deep learning, and students have generally commented positively on it. However, it takes me about one hour per exam to grade- thus, it is nearly a week of work to grade exams for 40 students. It seems that student learning could be enhanced if I could design an assessment activity that they would have some role in grading themselves, and was perhaps more tailored to the real world.

Table 6. Current assessment tasks in Environmental Problem Awareness.

Activity	**Contribution to Final Grade**
Group presentation on Swedish environment	10%
Research Paper – turn in on Live @ Lund	30%
Group Presentation on data from Breanäs	10%
Final Exam – in class	50%

5.3 Revised Assessment Tasks for Earth Systems Science

I plan to keep the main assessment tasks from the current course structure; their alignment with the intended learning outcomes is shown below in Table 7. However, I will make modifications to the structure of the tasks to promote deep learning.

Specifically, with regards to the **Pre-Course Assignment**, I will develop a grading rubric based on the criteria of Diederich (1974) in Table 5, similar to the grading rubric in Biggs and Tang (2011:240). This will be used by both tutors and a peer to assess student's papers. Students will then revise their papers, taking this feedback into account. The revised papers will be assessed by another peer using the rubric, and by the students themselves, to determine a grade. For grades that agree within 10%, that grade will be assigned. For grades that vary by more than 10%, I will read the paper and provide the grade. We will have a writing workshop in class where we discuss and use both good and bad (anonymous) examples and work through how to improve them.

Table 7. Proposed assessment tasks in Earth Systems Science and their alignment with the Intended Learning Outcomes.

Condensed Intended Learning Outcome (see Table 2 for full list)	**Assessment Task**
1. physical, chemical, and biological aspects of Planetary Boundaries	Final exam
2. Scientific research process	Group Project
3. visually and statistically represent, analyze, and interpret quantitative data	Final exam Final paper
4. Demonstrate skills in academic writing	Pre-course Assignment Group Project
5. Leadership, communication, and effective group work	Sweden presentation Group project contract Final presentation
6. Analyze and evaluate local solutions	Group Project

For the **Group Project**, students will be assigned to groups that are diverse in terms of gender, nationality, disciplinary background, and personality. As described above, they will design and carry out a data collection experiment in Lund after the fieldwork trainings in a small group of about six, then write up the results in pairs. They will revise their results after a peer-review session and submit papers in pairs, which will receive detailed feedback from me. They will make a **final presentation** as a larger group, where they both explain their process and results. This means that the majority of teacher feedback will come on an in-depth project where students have invested substantial time, in line with recommendations to promote deep learning (Biggs and Tang, 2011); this intensive focus on writing will replace the essay question in the exam.

For the final exam, I will implement several changes. First, at the end of each lecture, I will have students submit possible exam questions, which I will draw from in writing the exam. This motivates student engagement and is also a good check of what they have understood at the end of class, and what needs to be clarified. Second, I will follow a modified version of the self-assessment approach described in Biggs and Tang (2011:229) in using student grading of exams as follows. Students will take the exam on a Friday. Over the weekend, I will develop a detailed model for the answer needed for full credit, compiled from the best student responses, and make photocopies of the exams, keeping the originals in my office. In class on Monday, I will hand out the photocopied exams, where each student (or possibly pairs of students) is responsible for grading one exam question for all exams relative to the rubric. They will arrange the responses into piles for each level of grade, and assess them against the rubric for consistency. Having done this and agreed on marks, they will turn in those exams and mark their entire exam against a rubric. I will then compile the two sources of grades: one from a different student for each question, and one for the whole exam by the student. If there is less than a 10% discrepancy between a student's own grade for their exam, and that of their peers, their own grade will be assigned. If there is more than 10% discrepancy, the teacher will read the exam and assign the grade.

6 Implementation and Responsibilities

This course draws on input from a large number of colleagues, particularly in organizing the small-group Pre-Course Assignment tutoring sessions, and in the field trip to Breanäs. Guest lectures from local authorities and from research colleagues will require coordination as well. I have outlined some key next steps for implementation in Table 8.

Table 8. Timeline and key responsibilities for tasks related to the proposed course redesign, broken down by intended learning outcome.

	Planetary Boundaries	Research process	Quantitative analysis	Academic writing	Communication	Local solutions
May			-Meet with Gen and Klara about tutoring	-Talk with Lena about PCA -meet with Britta about library training	-Request student input for Breanäs training	-Get suggestions from Bodil and Ann on local speakers
June	-Reading list and accompanying videos	-Design Breanäs stations -Order field equipment	-Reading list and videos -Align analysis with Planetary Boundaries and select statistics to compliment this	-Writing Revolution exercises -List of LU resources -Send PCA to students -Line up tutors for PCA's	-Write groupwork contract and present at teacher's meeting	-Contact local speakers and arrange for field trips -Scout out field sites
August	-Lecture and activity design	-Hypotheses exercises	-Revise R tutorials for content relating to Planetary Boundaries			

7 Feedback from Critical Friends and Reflection

I have presented this project as a work in progress with several colleagues, who have provided valuable feedback. I sent a draft to all the teachers in my departmen and invited them for a fika to share their ideas, where five people attended. I also received one-on-one comments from three additional colleagues. These consultations with "critical friends" were extremely valuable in improving the course design, better integrating it with the overall curriculum, and in fostering a spirit of collaborative engagement with and feedback on teaching as a scholarly activity in the "critical tradition in academia", similar to how research is typically viewed (Handal, 1999).

As a result of input from colleagues, as well as feedback received from peers in the LATHE course, I made the following changes:

- Added critical reflection on the Planetary Boundaries concept, to avoid overly simplistic embrace of it or any other framework.
- Changed the research project to be based locally in Lund, and made linking local and global issues an intended learning outcome.
- Added space for guest researchers to present to students.
- Changed the Breanäs activity to match the Planetary Boundaries concept, and engaged with the Breanäs team to redesign this field activity.
- Removed an initial list of challenges in the Introduction to this document, and incorporated them where relevant in the text.
- Refined the description of the evolution of the Seven Challenges to Sustainability based on conversation with colleagues.
- Agreed to include explicit discussion of research paradigms from the first class, to set the tone for later variation in this across the program.
- We also discussed the idea of hosting teacher exchanges, where we visit eac other's classes to observe and participate and learn from each other.
- Shortened the theoretical discussion of learning taxonomies and moved the comparison between them to an Appendix, upon learning that we were no longer obligated to follow the previous division of learning outcomes.

As part of the feedback fika, we discussed the need to align the overall MSc progra learning outcomes with what is taught throughout the program, and with the five competencies for sustainability from Wiek et al. (2011). We agreed that this will b an ongoing, collective effort for the fall and beyond. To assist this process in gettin started, I plan to present a summary of this project and the constructive alignment process used to design it at a Monday lunch seminar, attended by all graduate students, postdocs, and faculty in our department. This short presentation will be a ongoing part of my evolution as a reflective teacher as I strive to continue to improve my approach to promoting deep learning about a critical topic for the future of both our students and the planet.

8 References

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9 Appendix 1: Learning taxonomies and the relationship between the Bologna Process and curriculum alignment.

Bloom's revised taxonomy contains 36 learning verbs at six levels, while the SOLO taxonomy contains 57 verbs at four levels. Of the 14 verbs shared between the two taxonomies, all but one ("perform") are classified in a similar relative position (e.g., the two taxonomies agree that "recall" and "recognize" are at the lowest level, while "develop" and "hypothesize" are at the highest level. Therefore, the selection between taxonomies is not as important as the awareness of the relative sophistication of the active learning verb at each stage.

Lund University is part of the Bologna process, which aims to standardize education across Europe to facilitate exchange between countries and universities (Biggs and Tang 2011, p. 3). According to this format, which my department has historically followed, intended learning outcomes should be divided into three separate domains: (1) knowledge and understanding; (2) skills and abilities; and (3) outcomes concerning critical judgment and evaluation. I see a parallel between this approach and that of the constructive alignment from Biggs and Tang (2011): each contains three elements of similar student learning, but the Bologna process splits them up separately under different headings, while Biggs and Tang integrate each of the three aspects within each ILO. I have summarized the similarities in Table 9.

Table 9. Comparison of the descriptions of three aspects of intended learning outcomes under the Bologna Process, and the curricular alignment model from Biggs and Tang.

Aspect of ILO covered	**Bologna process**	**Constructive Alignment from Biggs & Tang, 2011**
Student abilities gained	Skills and abilities	Active verb
Topic or content	Knowledge and understanding	Substance
Level of mastery	Critical judgment and evaluation	Level of mastery gained, quality expected

I find the integrated approach to connect student action, subject matter, and level of mastery more useful than separating them, and will use this approach here. I think it is more clear both for the student, and for designing and assessing learning activities. For example, I found the exercise of ensuring that content was clearly related to the action that would be performed on this subject useful in formulating research aims in writing a recent grant proposal. One of my initial research aims was to:

Quantify and map the key foods currently being eaten in Sweden, including their geographical source and production system of origin.

Aligning one verb or action per subject area resulted in the following revised goal, which I think is more clear:

Quantify the key foods currently being eaten in Sweden, map their geographical source, and characterize their production system of origin.

For the grant proposal, I left out the fact that I expect to do this with a high degree of sophistication and creativity!