

Systems Thinking in Science Education and Outreach toward a Sustainable Future

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SUPPORTING INFORMATION

FOR THE INSTRUCTOR

Four projects are included that encompass systems thinking, problem-based learning, and community service-based learning. They were all carried out in nonmajors Environmental Science courses at Pasadena City College (PCC). For each, there is a description of the project, including the overall project goal, directions to the student, a rubric, and a timeline for implementation of the project in your course. Each project is accompanied by a post-assignment reflection prompt.

ENVIRONMENTAL SCIENCE PROJECTS

ENVS 2: 'HUMAN IMPACT ON THE ENVIRONMENT'

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ENVS 2: 'HUMAN IMPACT ON THE ENVIRONMENT'

PROJECT 1: QUANTIFY SELF

GOAL OF PROJECT: Quantify your environmental impact using the scientific method.

Directions to the Student.

What is YOUR environmental impact?

In this project, you will first state a hypothesis about your environmental impact (prediction).

You will then collect data for 3 days.

Keep a reflection journal, and write down everything you consume and use for 3 days. This includes electricity, clothing, food, water, transportation, etc. You will also keep track of everything you throw away (write it down in your reflection journal). Note whenever you use clean water. Be observant!

Then, after 3 days of doing this, you will summarize your data (use tables/graphs/charts) and draw major conclusions from your findings. Write a reflection about whether your prediction matched your data collected and specific aspects that did or did not surprise you (referencing your collected data in your argument).

Be sure to calculate your greenhouse gas emissions, carbon footprint, and pounds of waste and water.

Here are some great apps/websites to help you collect your data and calculate your impact:

<https://joulebug.com/>

<https://www.epa.gov/energy/measure-impact-your-energy-use-environment>

Please submit your write-up (through Canvas) that includes a presentation of your hypothesis, methodology of data collection, results, analysis, major conclusions, and thoughtful reflection.

RUBRIC:**Quantify Self Project****Quantify Self Project**

Criteria	Ratings	Pts
HYPOTHESIS and EXPERIMENTAL DESIGN	<p>30.0 pts A clear hypothesis is stated regarding your environmental impact [15 points]. A description of the methodology of your data collection is clearly outlined with relevant references and resources, such as websites planned to be used to collect data [15 points].</p>	30.0 pts
DATA COLLECTION and ANALYSIS	<p>40.0 pts Notebook with collected data is clearly annotated, described, dated, and reflected upon [15 points]. Appropriate charts, tables, graphs, and other means of representing your data are clearly constructed, labeled, and effectively communicate the results of your data [15 points]. A clear conclusion is written describing the analysis of your results and the connection to sustainability [10 points].</p>	40.0 pts
PRESENTATION OF PROJECT RESULTS	<p>30.0 pts QS project presentation is clear, concise, and objective and it contains the following elements: introduction with hypothesis [5 points], methodology of data collection [5 points], results using aesthetic and effective charts, tables, graphs, etc. [5 points] analysis of results, reflection and connection to sustainability [5 points], references [5 points], overall aesthetics and well-rehearsed presentation to effectively communicate science to the class [5 points].</p>	30.0 pts
Total Points: 100.0		

REFLECTION PROMPT:

Describe what you learned from the QS project about your environmental impact. Did it match your prediction? Why or why not? How did you implement the scientific method in your project? How is conducting sound science, as well as scientific communication, important in environmental science and addressing socioenvironmental issues? What were your 3 biggest takeaways from QS?

QUANTIFY SELF PROJECT

Project Overview for the Educator.

The overall goal of project is for students to quantify their environmental impact using the scientific method and practice scientific communication by presenting their results to the class.

You can begin by introducing the scientific method and doing a number of activities to engage the students with the iterative nature of our method and provide them with practice¹. You can teach the concepts of sustainability and carbon footprint² and show data regarding human environmental impact³. This can follow class discussions about the anthropocene⁴ and planetary boundaries^{5, 6}. Assign the students data collection for 3 days (this data collection portion can be extended if you would like). You can show students websites for tracking their carbon footprint and sustainability actions, such as through the Environmental Protection Agency⁷ and other engaging sustainability apps, such as Joulebug⁸. Allow students 1 week to analyze and interpret their data with tutorials on how to use Excel and other data analysis/tabulation tools if necessary. The students will present their findings to the class the following week.

PROJECT TIMELINE:

WEEK	ACTIVITY
1	Introduction of ENVS concepts and the scientific method
2	Student data collection
3	Data analysis/interpretation
4	Presentation of QS projects

PROJECT 2: BE A CHANGE AGENT

Directions to the Student.

GOAL OF PROJECT: The overarching goal of *Env Sci 2: Human Impact on the Environment* is environmental awareness, education, and motivation to make a positive change and lead by example. In Quantify Self, you measured your own impacts by collecting/analyzing data. Now, for your final project, you will identify a way that you can make an impact in your local community as an environmental steward. It is important to conduct some background research about how you want to affect positive change (maybe you already have done so as a result of this class; feel free to use the articles and materials posted on Canvas). It is very important to design a method to measure the impact of what you do in the community (i.e. online comments from a social media campaign or editorial; pictures of a plastics cleanup; evidence and data collection from a scientific invention; video from an environmental awareness project; [Google] surveys from an education/outreach project, etc.). The possibilities for this project are endless, and it is up to you to be creative so that you can:

‘Be the change you wish to see in this world.’ -*Ghandi*

You should pick something that you realized through Quantify Self, or that resonated with you in this class, or that you discovered through your assigned readings or studies, or that you see daily as you have now become more observant of your own practices and those of your families and friends.

You can use the inspirational student models from the ‘Agents of Change’ sections of our textbook².

Dr. jB’s advice is to pick something you are passionate about!

Your presentation should contain:

- Title slide with a creative title for your project
- Intro/background of why you chose this project (i.e. Was it from internal motivation? Was it from an observation you made about an environmental concern? Did it come from something measured in Quantify Self?)
- What you did and how you planned to measure the impact
- Your results/measured impact (surveys, responses to online editorial, videos, pictures, etc.)
- What you learned from doing this project
- Outlook/future directions (do you plan to continue the project when you transfer or here at PCC? Do you plan to modify it? Did it inspire you to join an organization, club, or advocacy group? Etc.)
- List of references [you must use articles to justify your project idea and to backup claims in your introduction]

RUBRIC:**Be a Change Agent Project****Be a Change Agent Project**

Criteria	Ratings	Pts
PROPOSAL	<p>30.0 pts A clear proposal for your project is articulated [15 points]. A description of the methodology of your data collection is clearly outlined with relevant references and resources, such as websites planned to be used to collect data [15 points].</p>	30.0 pts
DATA COLLECTION	<p>40.0 pts Collected data is clearly annotated, described, dated, and reflected upon [15 points]. Appropriate charts, tables, graphs, and other means of representing your data are clearly constructed, labeled, and effectively communicate the results of your data [15 points]. A clear conclusion is written describing the analysis of your results and how it impacted the community in terms of sustainability [10 points].</p>	40.0 pts
PRESENTATION OF PROJECT and ITS IMPACT	<p>30.0 pts Project presentation is clear, concise, and objective and it contains the following elements: introduction with hypothesis [5 points], methodology of data collection [5 points], results using aesthetic and effective charts, tables, graphs, etc. [5 points] analysis of results, reflection and connection to sustainability [5 points], references [5 points], overall aesthetics and well-rehearsed presentation to effectively communicate science to the class [5 points].</p>	30.0 pts
Total Points: 100.0		

REFLECTION PROMPT:

Describe what you learned about environmental stewardship from the 'Be a Change Agent' project.

Do you now consider yourself an 'Agent of Change'? Will you continue these efforts once the course is over? If so, in what ways? What were your 3 biggest takeaways from this project?

BE A CHANGE AGENT PROJECT

Project Overview for the Educator.

The overall goal of project is for students to become environmental stewards and participate in community service-based learning. You can introduce the idea about the project in the first few weeks of the course and intermittently show the students examples of other undergraduate students who have become an ‘Agent of Change’ (see *Environment and You* text sections called ‘Agents of Change’ for ideas²). Each time there is an idea brought up in class in which students can make an impact in the environment or community, this can be acknowledged, such as microplastic contamination, air pollution, energy conservation, composting, waste, etc. This is given as an individual Final Project, so projects are typically presented in the last week of the course. The students will submit proposals during Week 4, which will be given feedback from the professor; revisions to the proposal will be due Week 5, and throughout the remainder of the course, there will be intermittent checks from the professor on student progress via ‘progress self-reports’ submitted online (through Canvas). The final projects are presented during the last few weeks of the course, which is followed by an individual project reflection submitted online (through Canvas).

PROJECT TIMELINE:

WEEK	ACTIVITY
1 (throughout course)	Introduction to environmental stewardship with ‘Agent of Change’ examples ²
4	Project proposals due
5	Project proposal revisions due
8	Progress self-report 1 due
9	Feedback from Prof. on progress self-report 1
11	Progress self-report 2 due
12	Feedback from Prof. on progress self-report 2
15	FINAL PROJECT presentations

ENVS 3: 'CHEMISTRY AND THE ENVIRONMENT'

PROJECT 3: Introduction to the UN sustainable development goals

Directions to the Student.

GOAL OF PROJECT: The goal of this group project is to introduce/teach the class about the UN sustainable development goals (SDGs)^{9, 10}. You will prepare a presentation and interactive discussion to teach your fellow classmates about your assigned UN SDGs.

For your 3 UN SDGs, create an infographic or presentation to inform the general public (your classmates) about each goal.

What exactly is the goal? Provide a brief description.

Why is it a goal towards sustainability?

What is the current progress towards the goal?

What are the targets and indicators?

How can an individual or a community accomplish this goal in their daily life?

How can chemistry be applied to solving the challenges inherent in this goal?

How does it relate to the Planetary Boundaries framework?

Put forth a proposal for your group to practice 1 action for the remainder of the course towards one of the UN SDGs. We will report out on your progress at the end of the semester.

References:

UN SDGs: <https://www.un.org/sustainabledevelopment/sustainable-development-goals/>

https://www.ted.com/talks/michael_green_the_global_goals_we_ve_made_progress_on_and_the_ones_we_hav_en_t?language=en

Please upload your presentation to Canvas by 4:59pm.

Include all group members' names on the presentation/graphic and make it clear which 3 UN SDGs you are addressing.

RUBRIC:

UN Sustainable Development Goals Group Project

UN Sustainable Development Goals Project

Criteria	Ratings	Pts
CONTENT	<p>50.0 pts</p> <p>INFOGRAPHIC or presentation created [5 points].</p> <p>Addresses each of the following points for each assigned UN SDG: What exactly is the goal? Provide a brief description. Why is it a goal towards sustainability? What is the current progress towards the goal? What are the targets and indicators? How can an individual or a community accomplish this goal in their daily life? How can chemistry be applied to solving the challenges inherent in this goal? How does it relate to the Planetary Boundaries framework?</p> <p>[5 points each x 7 = 35 points]</p> <p>Proposal for your group to practice 1 action for the remainder of the course towards one of the UN SDGs [10 points].</p>	50.0 pts
PRESENTATION QUALITY	<p>25.0 pts</p> <p>INFOGRAPHIC: images are clear and captivating with a clear message and logical flow to impart meaning. It is captivating and engaging to an audience of non-scientists.</p> <p>PRESENTATION: slides have clear messages, aesthetic and effective images, simple phrases and points, and are not overcrowded with information. Presentation is captivating and engaging to an audience of non-scientists.</p>	25.0 pts
INTERACTIVE DISCUSSION / ENGAGEMENT	<p>25.0 pts</p> <p>Clear discussion questions are crafted based on your assigned SDGs. Discussion is entertaining and engages the audience, and it is still informative and captures points that you made in your presentation/lesson. There are at least 3 major points discussed from your presentation.</p>	25.0 pts
Total Points: 100.0		

PROJECT 4: Chemistry, sustainability, and your career

Directions to the Student.

GOAL OF PROJECT: In this project, you will create a short visual presentation or video showing how your chosen career connects to chemistry and sustainability. Be mindful of the PB framework, green chemistry, and the UN sustainable development goals.

RUBRIC:

Career + Sustainability Project

Career + Sustainability Project

Criteria	Ratings	Pts
CONTENT	50.0 pts The video or visual presentation depicts an accurate representation of how sustainability, PB framework, and the UN sustainable development goals can be incorporated into your chosen career (think of the day to day responsibilities, materials produced, materials consumed, waste generated, influence over others, etc.). Important criteria one would consider for this presentation are 1) explain the career to your peers and the education required; 2) type & amount of human interaction and ways to impact others to incorporate sustainable practices, 3) the physical environment and materials created, and 4) innovation in terms of sustainable development and the future of the career.	50.0 pts
PRODUCTION QUALITY	20.0 pts Video: Scenes flow in a logical way which reflects effective planning. Screenshots, background, and props support the scenes rather than detract from them. Audio is clear and understandable. Soundtrack enhances video and is appropriate. Presentation: slides contain images that are well described (but not too many words on slides); message and descriptions are very clear.	20.0 pts
ENGAGEMENT	30.0 pts Video/presentation is entertaining and engages the audience. If doing a video/skit: actors have memorized their lines and action seems natural. If doing a presentation, it is well rehearsed. Video/presentation demonstrates aspects such as humor or cleverness to appeal to the audience.	30.0 pts
Total Points: 100.0		

CHEMISTRY, SUSTAINABILITY, AND YOUR CAREER: connecting the UN sustainable development goals, planetary boundaries framework, and green chemistry to your career

Project Overview for the Educator.

The overall goal of project is to connect sustainability to student career pathways. If conducted in a nonmajors course, there are a range of different career pathways that you can group students according to (i.e. fashion, psychology, art, STEM, business) and if this is done in a majors course, this can still be done (i.e. physician, dentist, biomedical researcher, physical therapist, biologist, chemist, etc.) You can introduce the concepts of green chemistry, PB framework and the UN sustainable development goals throughout the course in a variety of ways. There are excellent resources below, including scientific articles that can be discussed and Ted talks that can be shown during class (see *References*). Typically, the following papers are assigned to teach the ideas behind the Anthropocene and PB and students present ideas and figures from the papers to the class.

- a. Waters, C.N. et. al. The Anthropocene is Functionally and Stratigraphically Distinct from the Holocene. *Science* **2016**, 351(6269), aad2622.
- b. Steffen, W.; Richardson, K.; Rockström, J.; Cornell, S. E.; Fetzer, I.; Bennett, E. M.; Biggs, R.; Carpenter, S. R.; de Vries, W.; de Wit, C. A.; Folke, C.; Gerten, D.; Heinke, J.; Mace, G. M.; Persson, L. M.; Ramanathan, V.; Reyers, B.; Sörlin, S. Planetary Boundaries: Guiding Human Development on a Changing Planet. *Science* **2015**, 347 (6223), 736–747.

This project should be completed after the ‘Introduction to the UN sustainable development goals’ group project described above in the *SI* (where student groups research 2-3 of the UN SDGs and present them to the class, which is followed by a reflection. Then, the class can watch a Ted talk about the UN SDGs and current progress towards them—see references section below.)

The career project is given as a Final Project, so they are typically presented in the last week of the course. The students will be surveyed about their majors, career goals and grouped according to careers in Week 8. The groups are given class time to brainstorm ideas and sign group contracts, and they set up an online collaboration to continue their work as a group, which is monitored by the instructor. Throughout the remainder of the course, there will be intermittent checks from the professor on student progress via 'progress self-reports'. The final projects are presented during the last few weeks of the course, which is followed by an individual reflection submitted online.

PROJECT TIMELINE:

WEEK	ACTIVITY
1	Introduction to Green Chemistry
2	Introduction to PB framework [Steffen <i>et al.</i>] and Ted talk.
3	Introduction to UN sustainable development goals [reference website and Ted talk]
6	Student presentations teaching about UN SDGs
7	Reflections on UN SDG presentations due
8	Career groups are assigned; brainstorming about project ideas is carried out; group contracts signed
10	Group progress self-report due
11	Feedback from Prof. on progress self-report
13-15	FINAL CAREER PROJECT presentations

FINAL PROJECT REFLECTION: Chemistry, sustainability, and your career.

PROJECT REFLECTION: Please write a 1-2 page reflection (1.5 spaced) about what you learned from exploring the ways in which your education (including chemistry) and sustainability connects to your chosen career. Discuss relevant aspects of the PB framework, UN SDGs, green chemistry, and sustainability education/community outreach related to your educational/career pathway. Be sure to apply the practical and personal connections to science and chemistry that are pertinent to everyday life on the job.

RUBRIC:

Career + Sustainability Reflection Rubric

Career + Sustainability Reflection Rubric

Criteria	Ratings					Pts
REFLECTION	25.0 pts Thoughtful completion of the reflection prompt with insight about connecting sustainability to your career.	19.0 pts The reflection prompt is not fully addressed / responses are not fully developed. Lacking insight about how sustainability connects to career.	13.0 pts The response to the reflection prompt is brief and lacking thought and insight. Very limited discussion about sustainability and its relation to career.	7.0 pts Extremely limited response to the prompt.	0.0 pts No response.	25.0 pts
Total Points: 25.0						

Relevant career applications:

Sustainability in fashion design
Sustainable design in business and marketing
Environmental awareness in pharmacy and medicine
Design of novel bioinspired materials as a bioengineer or biological researcher
Design of ways to naturally biodegrade oils and microplastics as a researcher
Chemist; Environmental Scientist
Environmental psychology
Psychology of climate change
Sustainable chemistry in the design of green chemicals and materials
Green information technology and computer science
Sustainability awareness in artistic fields (i.e. music, writing novels, advertisement, screenplays)
Sustainable energy engineers, such as solar, biofuels, wind, biomass, etc.
Sustainable agriculture, farming, and food production
Sustainability education (formal in classroom settings and informal in museums and through outreach)

REFERENCES

1. Understanding Science. <<http://undsci.berkeley.edu/>> (accessed Oct 2019).
2. Christensen, Norm. *The Environment and You*. 3rd edition, Pearson Education: London, United Kingdom, **2019**.
3. Global Climate Change; Vital Signs of the Planet: <<https://climate.nasa.gov/>> (accessed Oct 2019).
4. Waters, C.N. et. al. The Anthropocene is Functionally and Stratigraphically Distinct from the Holocene. *Science* **2016**, 351(6269), aad2622. DOI: 10.1126/science.aad2622.
5. Stockholm Resilience Centre. The Nine Planetary Boundaries. <<https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html>> (accessed Oct 2019).
6. Steffen, W.; Richardson, K.; Rockström, J.; Cornell, S. E.; Fetzer, I.; Bennett, E. M.; Biggs, R.; Carpenter, S. R.; de Vries, W.; de Wit, C. A.; Folke, C.; Gerten, D.; Heinke, J.; Mace, G. M.; Persson, L. M.; Ramanathan, V.; Reyers, B.; Sörlin, S. Planetary Boundaries: Guiding Human Development on a Changing Planet. *Science* **2015**, 347 (6223), 736–747.
7. U.S. EPA: Measure the Impact of Your Energy Use on the Environment. <<https://www.epa.gov/energy/measure-impact-your-energy-use-environment>> (accessed Oct 2019).
8. JouleBug Sustainability App. <<https://joulebug.com>> (accessed Oct 2019).
9. United Nations Sustainable Development Goals. <<https://sustainabledevelopment.un.org>> (accessed Oct 2019).
10. Anastas, P. T.; Zimmerman, J. B. The United Nations Sustainability Goals: How Can Sustainable Chemistry Contribute? *Curr. Opin. Green Sustain. Chem.* **2018**, 13, 150–153.
11. Anastas, P. T.; Warner, J. C. *Green Chemistry: Theory and Practice*, Oxford University Press: New York, **1998**, p.30. By permission of Oxford University Press. <www.acs.org/greenchemistry> (accessed Oct 2019)
12. Citizens' Climate Lobby: Writing Effective Letters to the Editor. <<https://community.citizensclimate.org/resources/item/19/111>> (accessed Oct 2019).
13. Wals, A. E. J.; Brody, M.; Dillon, J.; Stevenson, R.B. Convergence Between Science and Environmental Education. *Science* **2014**, 344(6184), 583–584.

Relevant Ted talks:

UN SDGs:

https://www.ted.com/talks/michael_green_how_we_can_make_the_world_a_better_place_by_2030?language=en

https://www.ted.com/talks/michael_green_the_global_goals_we_ve_made_progress_on_and_the_ones_we_haven_t?language=en

PB:

https://www.ted.com/talks/johan_rockstrom_let_the_environment_guide_our_development?language=en

https://www.ted.com/talks/johan_rockstrom_5_transformational_policies_for_a_prosperous_and_sustainable_world?language=en

Our Changing Climate. <https://ed.ted.com/series/?series=our-changing-climate>