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A project module in an upper-division Thermodynamics course that addresses EOP Systems Thinking

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She received a Dipl. Ing. degree in mechanical engineering from Belgrade University and an M.S.M.E. and a Ph.D. from the University of Washington. She has held the title of Paccar Professor and is an Affiliate Professor at the University of Washington.

A Project Module in an Upper-division Thermodynamics Course that Addresses EOP Systems Thinking

Abstract
Engineering for One Planet (EOP) has designed a framework of student outcomes (Framework) intended to be a tool for transforming engineering education to one that enables engineers to provide engineering "solutions while minimizing potential negative environmental consequences." The Framework outlines nine outcome categories, including systems thinking, environmental literacy, social responsibility, responsible business and economy, environmental impact measurement, materials choice, design, critical thinking, and communication and teamwork. This Framework also includes learning outcomes that enable assessment of students' ability to design and formulate solutions while minimizing negative environmental and social consequences. Aspects of this broad Framework can be applied throughout an engineering curriculum, but that commands the development of a new mindset for faculty and students. This new mindset requires a fundamental change to how engineering is taught.

This paper focuses on implementing two EOP Systems Thinking outcomes in a 4th-year Thermodynamics course. The outcomes are:

EOP Systems Thinking 1: "Explain interconnectedness (e.g., intersecting, related and/or connected systems; human actions and global environmental and social impacts and consequences; synergies and rebound effects) and how all human-made designs and activities rely upon and are embedded within ecological and social systems"

EOP Systems Thinking 3: "Apply relevant concepts from required disciplines to the study of real-world problems and their solutions with empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness.

These outcomes are addressed in a 3-week project assigned in the class. Students are asked to recommend whether a condensing furnace run on natural gas or a heat pump should replace an old natural gas furnace in a private home. While some may find this to have an obvious engineering solution, the answer is not straightforward when considering the broader effects. The idea is to increase system boundaries beyond the design objects to include the environment, society, and culture. Students are expected to analyze options by performing technical calculations in specific societal and cultural contexts, use appropriate engineering codes, familiarize themselves with existing and future laws, and consider public health, safety, and welfare in evaluating their solutions' global, cultural, social, environmental, and economic implications.

The class is taught in a flipped (inverted) format. Students are required to watch videos that address technical background knowledge. They are expected to research the codes, laws, and other inputs, and a program manager for residential space heating from a local utility is invited to speak about applications and answer students' questions. A philosophy professor provides a

lecture on broader societal and cultural implications. A professional engineer provides a lecture on heat pump and furnace applications.

The students' responses to the project and applied pedagogy were positive, and their presentations show evidence of applying broader contexts in evaluating engineering solutions.

The paper includes descriptions of the project, deliverables, theoretical framework, applied pedagogy, a grading rubric, and examples of student work. It also details designing this course module for applications in learning management systems, such as Canvas.

Introduction

Seattle University received an ASEE Engineering for One Planet mini-grant [1], supported by the work funded by the Lemelson Foundation [2] in 2024. The ASEE EOP program aims to "incentivize faculty to integrate concepts of sustainability into their curricula" [1]. The sustainability concepts are defined in terms of student learning outcomes for engineering education [3]. Two of those outcomes are the EOP Systems Thinking 1 and 3, quoted in the Abstract.

Before obtaining this grant, our university community began a five-year strategic plan "Reigning our Strategic Directions 2022-2027," which includes an effort to reimagine and revise our curriculum [4]. The campus is also strongly committed to sustainability, evidenced in decades of environmentally-conscious initiatives by the university facilities departments and the support for the decade-old Center for Environmental Justice and Sustainability [5,6].

This grant was awarded to three engineering departments: Civil and Environmental, Electrical and Computer, and Mechanical Engineering. It now involves six engineering faculty members, four faculty members from across campus, including Environmental Studies, Philosophy, and Marketing, and two partners from local utilities. All six interdisciplinary two-person teams, comprising an engineering faculty member and a non-engineer or industry professional, are tasked with creating course modules that address at least two sustainability dimensions.

This paper focuses on one module designed to address EOP Systems Thinking 1 and 3 outcomes and contains the following sections: course description and applied pedagogy, project assignment and pedagogy, project deliverables and observations, conclusions, appendix 1 and appendix 2.

Course description and applied pedagogy

The fourth-year Thermodynamics course focuses on applications of theoretical thermodynamics principles. It is designed for students to learn energy systems fundamentals, develop an understanding of how energy systems affect the environment, climate, and society, and prepare them for engineering practice, i.e., to work on practical engineering problems. The course prerequisite is an introduction to Thermodynamics course, offered in the 3rd year.

Students can apply their knowledge from this course to energy systems in buildings, vehicle design, design of electronics, and many other applications. It prepares students to enter the thermal engineering profession by training them to apply theoretical concepts learned in the first thermodynamics course to real-world problems.

The course content is flipped (inverted classroom) [7], and the learning is project-based. Students watch lectures outside class time and work on assigned projects during class time. All project work is in teams, and individual knowledge is periodically assessed. The course is offered as a three quarter-credit course, with 150 minutes of class time per week divided into two 75-minute class periods per week. Students are expected to work about six hours outside of class time by watching lectures, reading assigned technical articles, studying, and conducting research related to the projects.

The database of lectures for this course was recorded, edited, and posted on Canvas. The lectures were recorded using voice-over PowerPoint presentations in a screen-capture format and edited using Camtasia. It was found that lectures take a shorter time when they are delivered in electronic format than when delivered in the classroom because they don't contain pauses typically associated with giving a lecture in person; however, students can pause and replay the electronic lectures if needed. The lectures were only 8-12 minutes long [7-9]. The list of lectures is below:

- Refrigeration Cycle Lecture
- Ideal Gas Mixtures
- Gas-Vapor Mixtures & Air-Conditioning
- Air-Conditioning , Human Comfort, & Psychrometric Chart
- Air-Conditioning Processes
- Cooling Towers
- Intro to Combustion
- Chemical Equilibrium
- First Law Analysis of Combustion Systems
- Adiabatic Flame Temperature
- Coal in the US
- Health Impacts of Coal Combustion
- E and Env Pollution and Intro
- E and Env Climate Change
- E and Env global climate change – E flow
- Rankine Cycle Intro and Reheat
- Rankine with Regeneration
- Cogeneration
- Boilers
- Brayton Cycle
- Gas Turbine Engine Applications
- Combined Cycles
- Intro to Exergy and 2nd Law Efficiency

- Quantifying Exergy and Exergy Change
- Exergy Balance

The assigned technical articles and web sites are listed:

- Finkelman, Robert B. “Health Impacts of Coal Combustion.” *USGS Fact Sheet FS-094-00* (July 2000).https://pubs.usgs.gov/fs/fs94-00/fs094-00.pdf
- Coal ash radioactivity https://www.scientificamerican.com/article/coal-ash-is-more-radioactive-than-nuclear-waste/
- Steffen, W. et al., “Trajectories of the Earth System in the Anthropocene” Proceedings of the National Academy of Sciences, www.pnas.org/cgi/doi/10.1073/pnas.1810141115, accessed on 9/26/2018
- Fork, D. and Koningstein, R. “Engineers: You Can Disrupt Climate Change. Decarbonization, carbon capture, and solar-radiation management will provide work for decades to come.” IEEE Spectrum, 28 Jun 2021, https://spectrum.ieee.org/engineers-you-can-disrupt-climate-change, accessed on 22 Sept 2021.
- Winters, J., “The Sunshine Solution” Mechanical Engineering, December 2008
- Dondur, N. et al. “Economic Analysis of Hydro-Geothermal Two Cascade Heat Pump – Serbian Case.” 4th International Symposium of Industrial Engineering, SIE 2009.
- McLinden, M.O., Seeton, C.J., Pearson, A., “New refrigerants and system configurations for vapor-compression refrigeration”, Science 370, 791–796 (2020)
- Stratospheric ozone layer protection: https://www.epa.gov/ozone-layer-protection
- Six criteria air pollutants: https://www.epa.gov/criteria-air-pollutants
- Annual Energy Review: https://www.eia.gov/totalenergy/data/flow-graphs/total-energy.php
- Climate change, local and global: https://www.epa.gov/climatechange-science
- International Energy Agency: http://www.iea.org/

The course's project-based learning is scaffolded. Students are alerted which lectures to watch and which articles to read before class so that their class time can focus on applying that knowledge to problem-solving. The approximate weekly topics and structure are shown in the table below. The project specifically aimed at assessing EOP Systems Thinking 1 and 3 outcomes is offered in weeks 3 through 5.

Week	Topics	Activities in class
1	Introduction to class, HVAC, Refrigeration	Small group project and a presentation
2	Intro to Combustion, environmental readings	HVAC Facilities Tour, Quiz, Project Assignment
3	Environmental Lectures and readings	HVAC PE Engineer Lecture on heat pumps and furnaces, Project Work
4	Chemical equilibrium, pollution, climate change, stratospheric ozone, coal, and health impacts of coal combustion	Lecture on societal impacts by a philosophy professor, Consultation with a utility program manager, and Project Work
5	Gas turbine engine applications and combined cycles	Project Work and final presentation

6	Boilers and Cooling Towers Rankine Cycle and Co-generation	Power plant tour and assignment
7		Power Plant Assignment working time
8	First Law Analysis of Combustion Systems and the Adiabatic Flame Temperature	Power Plant Assignment working time and report submittal
9	Quantifying Exergy, Exergy Balance, and 2^{nd} Law Efficiency	Problem-solving and a quiz
10	Broader energy topics	Guest lectures

The learning outcomes of the course are:

1. Draw the following cycles in T-s and h-s diagrams, and calculate their first and second law efficiencies, work (power) output, heat in, and heat out: Reheat/Regenerative Rankine, Co-Generation, and Combined Cycles
2. Draw refrigeration (heat pump) cycles in T-s and p-h diagrams and calculate their first and second law coefficients of performance, work (power) input, heat in, and heat out
3. Apply energy and mass conservation equations to determine thermodynamic properties of fluids passing through turbines, pumps, compressors, nozzles, diffusers, heat exchangers, including boiler, heat recovery steam generator, closed and open feedwater heater, intercooler, reheater, regenerator, and cooling towers
4. Write energy, entropy, and exergy balance for control volume, closed system, steady or unsteady flow process applications. Calculate reversible work and second law efficiency.
5. Calculate useful work potential (exergy) of a pure substance for a specified state of that thermodynamic system and of its environment
6. Calculate thermodynamic properties and composition of ideal gas mixtures, either in equilibrium or not
7. Estimate products of combustion for given quantities of fuel and oxidizer, assuming complete combustion or products in equilibrium at specified temperature and pressure
8. Apply energy conservation equation to calculate heat released during a steady-flow combustion process for a known quantity of fuel and oxidizer at a specified temperature and pressure of reactants and products
9. Calculate the adiabatic flame temperature for a known quantity of fuel and oxidizer
10. Demonstrate knowledge of the major boiler components, such as the fuel injectors, the drum, and the heat exchangers: water walls, super heaters, reheaters, economizer, air preheater. Name primary modes of heat transfer in each of the heat exchangers
11. Name major pollutants from coal, natural gas, gasoline, and diesel combustion and how they affect the environment and human health
12. Apply knowledge of subjects covered in class to understand modern technology, class tours, and to write a project report
13. Relate engineering design decisions to global, cultural, social, environmental, economic, public health, safety and welfare considerations
14. Identify the public health, safety and welfare consideration associated with a design task

15. Identify the global, cultural, social, environmental, and economic considerations associated with a design task

Skills that students gain in this class that they can put on their resume are:

- Analysis of complex systems
- Thermal systems design
- Experimental design
- Analyze and interpret experimental data
- Decision-making in broader contexts, incl. environmental, economic, societal
- Effective communication, including writing, presentation, video, and in-person
- Effective teamwork

Project assignment and pedagogy

The project is assigned to students via a learning management system (Canvas) module and in-class project introduction and discussion.

Pedagogically, students are asked to read through the module for a couple of minutes and then to discuss the project in pairs for two minutes. Then, they are encouraged to ask questions. Afterward, students are assigned into teams of 3-4 students, and the faculty guides a discussion by asking teams about what they think should be considered in solving this problem. Students use knowledge from assigned readings and lectures to formulate technical problems and grasp how their solutions might affect society and the environment. They are asked to brainstorm in their teams, ask questions, begin to form a plan for solving this project and begin to identify resources.

In the next class period, a philosophy professor gives a lecture on “Ways of Knowing” that puts technical decisions into a broader context, based on the book *Braiding Sweetgrass* by Robin Wall Kimmerer. He engages students in a discussion that is not technical. The following class period, a program manager for residential space heating from a local utility talks about the programs, support, and incentives from the utility, city, and state. They provide resources for the students relevant to the project. The faculty guides the technical considerations. In the following two class periods, the students work on the project in class. During the project work, the faculty works with each team individually and periodically engages the entire course in discussions. Students are encouraged to ask questions throughout the project work. On the final day, students present their findings in 20-minute team presentations.

The class project is designed to address ABET EAC Criterion 3 student outcome 2 (an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.) [10] and EOP Systems Thinking 1 and 3 outcomes.

The Project Assignment on Canvas has the following text:

A house in Bellevue, WA is looking to replace its 1987 natural gas furnace with either a new and more efficient natural gas furnace or a new heat pump. Please compare the two solutions' cost-effectiveness, environmental, and social impacts. Please explain the interconnectedness of your design and the ecological and social systems. Please apply relevant technical concepts with empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness.

Please justify your reasoning with the following:

- Appropriate technical calculations,
- Considering public health, safety, and welfare, and
- Considering global, cultural, social, environmental, and economic implications.

When gauging how to approach this presentation, imagine that the evaluator is a technical person who should be convinced that your solution is justified.
HINT: Please perform calculations to support your solution. You may use your theoretical knowledge, required readings, and your research to analyze your solution. Also, answer for yourself, the following questions:

What are the environmental effects of burning natural gas in a home furnace? How do those change when the furnace efficiency improves? What societal (health, social, etc) and economic effects may result when the furnace is changed or a heat pump is used? Where does the power to run a heat pump come from? What is the primary source mix by that utility? What is the law? What are the applicable building and energy codes in the city and the state? Are there new codes that will be implemented soon, and when? Are HPs required and nat. gas furnaces banned? Are there any incentives and rebates available for either solution? How does COP change with temperature? How do you operate HP: continuously or intermittently? How do you estimate the social and environmental impact of an HP and a furnace?

The project work will be evaluated using the following criteria:

- Quality of the technical solution
- Extent of considering public health, safety, and welfare in the proposed solution
- Extent of considering global, cultural, social, environmental, and economic implications of the proposed solution
- Quality of explanation of the interconnectedness (e.g., intersecting, related and/or connected systems; human actions and global environmental and social impacts and consequences; synergies and rebound effects) and how all human-made designs and activities rely upon and are embedded within ecological and social systems
- Solution is created by applying relevant technical concepts with empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness.

The module guide, including the evaluation rubric, is included in this paper in the Appendix 1.

Project deliverables and observations

Students enjoyed working on this open-ended project. They appreciated the guidance from the guest speakers and embarked on their own research. Team presentations contained assumptions, technical calculations on the equipment size, equipment cost, installation and maintenance cost, combustion emissions calculations, and considerations of environmental, cultural, societal, safety, and other impacts. Three examples of final presentation slides are provided in the Appendix 2 to illustrate how students addressed some of those issues.

The students' response to the course was overwhelmingly positive. Below are three quotes made by the students in the end-of-quarter teaching survey:

I really liked the projects that we worked on. The projects really helped me understand how to utilize the tools and information I was taught in lecture and the textbook. I was able to apply knowledge to real world situations and real world projects.

I felt like that we were able to ask a lot of questions and we were given the time to do the project in class and ask questions as we go. I think for me that simulated a much more real world experience because in real life I would ask questions as I go (work) rather than reading from a textbook and then coming up with questions when I have no idea how the problem would actually occur in a real life situation.

We were always encouraged to ask questions. It was not expected to have questions right away like some other professors would expect. Dr. Shuman encouraged us to work and ask questions as we came across them which allowed us a lot of time to problem solve and really understand what we didn't understand. She taught the class like a real world project team. I appreciated that we were pushed to focused on the knowledge, information, and project work rather than focusing on meeting deadlines with partial understanding, only hoping for a good grade.

Conclusions

This three-week project in a three quarter-credit upper thermodynamics course aims to integrate ABET EAC Criterion 3 student outcome 2 and EOP Systems Thinking 1 and 3 outcomes with a project-based learning module in a flipped (Inverted) classroom. External speakers and interactive pedagogy were applied to enhance student learning. The project module is included in the paper. Student presentations showed evidence of applying broader contexts in evaluating engineering solutions. Teaching evaluations show appreciation for the "real-world" projects and the pedagogical approach.

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APPENDIX 1

Module Title

EOP Systems Thinking in an upper-division Thermodynamics course

Student-focused synopsis of activity

This three-week module asks students to design devices by performing technical calculations and analyzing them in broader contexts. Topics include setting broad system boundaries, empathic and ethical considerations, local political landscape, societal and cultural awareness, and environmental and economic impacts.

Learning Objectives:

1. Relate engineering design decisions to global, cultural, social, environmental, and economic impacts and consequences
2. Apply fundamental engineering calculations and methods to solve a design problem while empathically and ethically considering communities/societies, environmental justice, and cultural awareness

3. Research and assess local energy policies and practices, cultural norms, and societal values
4. Communicate the problem and solutions to affect broader society

Objectives (can relate to EOP modules)

EOP Systems Thinking 1: "Explain interconnectedness (e.g., intersecting, related and/or connected systems; human actions and global environmental and social impacts and consequences; synergies and rebound effects) and how all human-made designs and activities rely upon and are embedded within ecological and social systems"

EOP Systems Thinking 3: "Apply relevant concepts from required disciplines to the study of real-world problems and their solutions with empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness.

Background information (1-2 pages of reading or a video would be appropriate.

Here is the list of required background lectures:

- Refrigeration Cycle Lecture
- Ideal Gas Mixtures
- Intro to Combustion
- Coal in the US
- Health Impacts of Coal Combustion
- E and Env Pollution and Intro
- E and Env Climate Change
- E and Env global climate change – E flow

Here is the list of required background readings:

- Steffen, W. et al., "Trajectories of the Earth System in the Anthropocene" Proceedings of the National Academy of Sciences, www.pnas.org/cgi/doi/10.1073/pnas.1810141115, accessed on 9/26/2018
- Fork, D. and Koningstein, R. "Engineers: You Can Disrupt Climate Change. Decarbonization, carbon capture, and solar-radiation management will provide work for decades to come." IEEE Spectrum, 28 Jun 2021, https://spectrum.ieee.org/engineers-you-can-disrupt-climate-change, accessed on 22 Sept 2021.
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- Winters, J., "The Sunshine Solution" Mechanical Engineering, December 2008
- Dondur, N. et al. "Economic Analysis of Hydro-Geothermal Two Cascade Heat Pump – Serbian Case." 4th International Symposium of Industrial Engineering, SIE 2009.

- McLinden, M.O., Seeton, C.J., Pearson, A., “New refrigerants and system configurations for vapor-compression refrigeration”, Science 370, 791–796 (2020)
- Stratospheric ozone layer protection: https://www.epa.gov/ozone-layer-protection
- Six criteria air pollutants: https://www.epa.gov/criteria-air-pollutants
- Annual Energy Review: https://www.eia.gov/totalenergy/data/flow-graphs/total-energy.php
- Climate change, local and global: https://www.epa.gov/climatechange-science
- International Energy Agency: http://www.iea.org/

Assignment prompt

A house in Bellevue, WA is looking to replace its 1987 natural gas furnace with either a new and more efficient natural gas furnace or a new heat pump. Please compare the two solutions' cost-effectiveness, environmental, and social impacts. Please explain the interconnectedness of your design and the ecological and social systems. Please apply relevant technical concepts with empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness.

Please justify your reasoning with the following:

- Appropriate technical calculations,
- Considering public health, safety, and welfare, and
- Considering global, cultural, social, environmental, and economic implications.

Detailed assignment guidelines (including any additional resources that are required)

When gauging how to approach this presentation, imagine that the evaluator is a technical person who should be convinced that your solution is justified.

HINT: Please perform calculations to support your solution. You may use your theoretical knowledge, required readings, and your research to analyze your solution. Also, answer for yourself, the following questions:

What are the environmental effects of burning natural gas in a home furnace? How do those change when the furnace efficiency improves? What societal (health, social, etc) and economic effects may result when the furnace is changed or a heat pump is used? Where does the power to run a heat pump come from? What is the primary source mix by that utility? What is the law? What are the applicable building and energy codes in the city and the state? Are there new codes that will be implemented soon, and when? Are HPs required and nat. gas furnaces banned? Are there any incentives and rebates available for either solution? How does COP change with temperature? How do you operate HP: continuously or intermittently? How do you estimate the social and environmental impact of an HP and a furnace?

Examples

Pedagogically, students are asked to read through the module for a couple of minutes and are then asked to discuss the project in pairs for two minutes. Then, they are encouraged to ask questions. After, students are assigned into teams of 3-4 students, and

the faculty guides a discussion by asking teams about what they think should be considered in solving this problem. Students use knowledge from assigned readings and lectures to formulate the technical problem and grasp how their solution might affect society and the environment. They are asked to brainstorm in their teams, ask questions, begin to form a plan for solving this problem, and begin to identify resources.
In the next class period, a philosophy professor gives a lecture on "Ways of Knowing" that puts technical decisions into a broader context, based on the book *Braiding Sweetgrass* by Robin Wall Kimmerer. He engages students in a discussion that is not technical. The following class period, a project manager from the local utility talks about the programs, support, and incentives from the utility, city, and state. The faculty guides the technical considerations. The following two class periods, the students work on the project in class, and on the final day, they present their findings in 20-minute team presentations.

Evaluation criteria

The project work will be evaluated using the following criteria:

1) Quality of the technical solution
2) Extent of considering public health, safety, and welfare in the proposed solution
3) Extent of considering global, cultural, social, environmental, and economic implications of the proposed solution
4) Quality of explanation of the interconnectedness (e.g., intersecting, related and/or connected systems; human actions and global environmental and social impacts and consequences; synergies and rebound effects) and how all human-made designs and activities rely upon and are embedded within ecological and social systems
5) Solution is created by applying relevant technical concepts with empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness.

Project evaluation rubric:

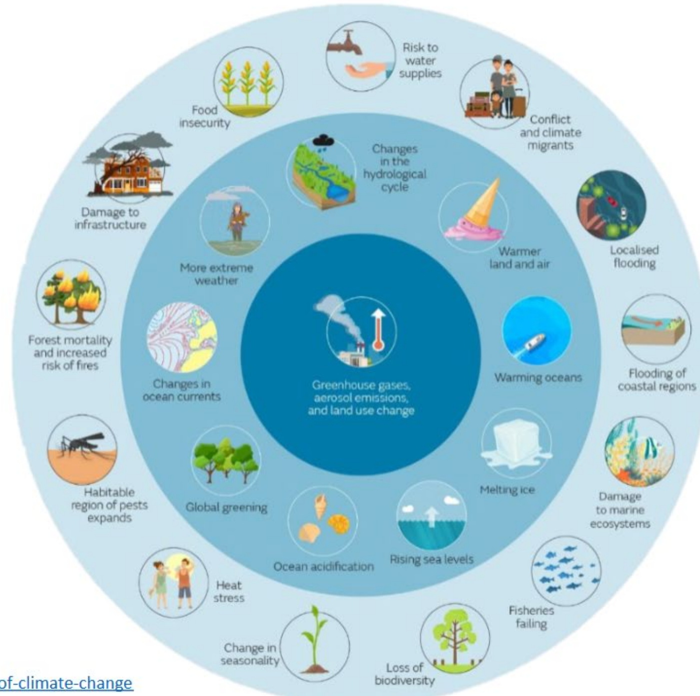
Technical solution quality			
20 A technically trained person can follow and fully comprehend the technical content, and the technical content is accurate	15 A technically trained person can follow and fully comprehend the technical content, and the technical content is mostly accurate	10 A technically trained person can follow and comprehend most of the technical content, or the technical content is inaccurate	5 A technically trained person cannot follow and fully comprehend the technical content, and the technical content is inaccurate

Considering public health, safety, and welfare			
20 Public health, safety and welfare are thoughtfully associated with the design task, and are informed and reasonable	15 Public health, safety and welfare are thoughtfully associated with the design task, but may be uninformed or unreasonable	10 Public health, safety and welfare are somewhat associated with the design task, and are uninformed and/or unreasonable	5 Public health, safety and welfare are not associated with the design task, and are uninformed and/or unreasonable
Considering global, cultural, social, environmental, and economic implications			
20 Global, cultural, social, environmental and economic considerations are thoughtfully associated with the design task, and are informed and reasonable	15 Global, cultural, social, environmental and economic considerations are thoughtfully associated with the design task, but may be uninformed or unreasonable	10 Global, cultural, social, environmental and economic considerations are somewhat associated with the design task, and are uninformed and/or unreasonable	5 Global, cultural, social, environmental and economic considerations are not associated with the design task, and are uninformed and/or unreasonable
Explain interconnectedness and how all human-made designs and activities rely upon and are embedded within ecological and social systems			
20 The interconnectedness of the design with the ecological and social systems is 1. thoughtfully related, 2. detailed evidence is provided, and 3. evidence is accurate	15 One of the three elements below is missing when describing the interconnectedness of the design with the ecological and social systems. 1. thoughtfully related, 2. detailed evidence is provided, and 3. evidence is accurate	10 Two of the three elements below are missing when describing the interconnectedness of the design with the ecological and social systems. 1. thoughtfully related, 2. detailed evidence is provided, and 3. evidence is accurate	5 Most of the three elements below are missing when describing the interconnectedness of the design with the ecological and social systems. 1. thoughtfully related, 2. detailed evidence is provided, and 3. evidence is accurate

Solution is created by applying relevant technical concepts with empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness			
20 Technical concepts are applied with empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness.	15 Technical concepts are applied but one is missing of: empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness.	10 Technical concepts are applied but missing several of: empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness.	5 Technical concepts are applied but missing empathic and ethical consideration for communities/societies, environmental justice, and cultural awareness.
Presentation Quality			
20 Requirements: 1. Length is less than 20 minutes 2. All information is placed in reasonable order 3. There are no spelling and other proofreading errors. 4. Slides are easy to read and follow	15 Missing one of the 4 requirements	10 Missing two of the 4 requirements	5 Missing three of the 4 requirements
Overall Score (sum of previous)			

APPENDIX 2

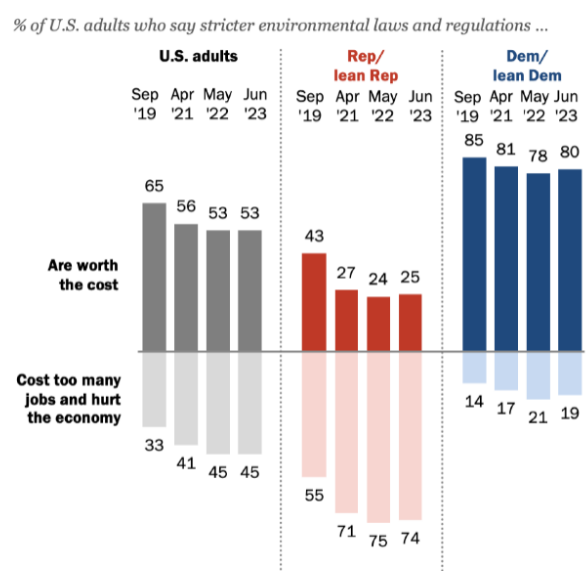
Cultural and Societal Impacts



(19) https://www.metoffice.gov.uk/weather/climate-change/effects-of-climate-change

American Culture and Climate Change

- Climate change is more akin to a sports match, pitting one side against each other
  - Caught in culture wars
- People filter scientific statements through their own world views
  - Cognitive filters reflect our cultural identity
  - Cultural identity can overpower scientific reasoning
- In the united states our opposing cultural worldviews map our partisan political system



(21) https://www.pewresearch.org/science/2023/06/28/3-majorities-of-americans-say-too-little-is-being-done-on-key-areas-of-environmental-protection/
(22) Hoffman, A. J. (2015). How Culture Shapes the Climate Change Debate. United States: Stanford University Press.

Safety

- Risk of gas leak and explosion
- Dangerous fumes released in household as aforementioned
- Needs to be serviced every 2 years for safety checks
- An explosion every two days in the U.S
- Heat Pump minimal risk of refrigerant leak