

ANALYZING PHYSICS STUDENTS' ETHICAL REASONING DURING A UNIT ON
THE DEVELOPMENT OF THE ATOMIC BOMB:
A CALL FOR MACRO-ETHICAL DISCUSSIONS
IN THE PHYSICS CLASSROOM

by

Egla K. Ochoa-Madrid, B.S

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Committee Members:

Alice Olmstead, Chair

Eleanor Close

Hunter Close

Ayush Gupta

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DEDICATION

I dedicate this page to my beautiful mother. Todo lo que hago, lo hago en su honor.

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ABSTRACT

The societal implications of technology developed through physics are not always clear. Physicists need to use ethical reasoning skills to maneuver through morally ambiguous situations. For this reason, curricula for physics students should also be geared towards developing these skills. This thesis focuses on the effects of ethical discussions in the physics classroom. I present an examination of physics students' engagement in a unit about the development of the atomic bomb through a two-part study where students interpret and apply an ethical framework to discussions about the development of the atomic bomb and current STEM research. Using both student written work and video-recordings of in-class discussions, I analyze how the curriculum design may influence student learning. Study 1 uses students' written work to understand how they interpret and apply an ethical framework to their discussions about the development of the atomic bomb and to current STEM research. Our analysis shows that students conflate certain ethical principles and/or avoid their negative implications, which in turn leads to a misapplication of the principles. However, students also demonstrate a range of productive approaches to applying these ethical principles which contribute to the development of strong ethical arguments. Study 2 uses video-recorded data of classroom interactions to understand how ethical discussions can be supported in the classroom. Our analysis shows the emergence of different group dynamics that seem to fall along a spectrum of engagement modes. The emergent modes are defined by the extent to which

students share a collective sense of what is going on in their group and build on each other's ideas. From the analysis, I consider how cues from the professor and LAs, as well as the availability of guiding prompts and other relevant curricular resources, influence these dynamics. I also share possible implications of these findings for instruction physics education researchers

1. INTRODUCTION

It is the job of physics educators to prepare physics students with the tools necessary to face the possible challenges in their students' future careers. These tools may include knowledge of a programming language, a fair understanding of calculus, and problem-solving skills. These are all technical skills that are associated with earning a Physics degree. However, the situations that physicists face are not limited to those that only require technical skills. Physicists are often seen as credible sources of information, and history tells us that physicists are capable of using this reputation to influence government policy and public opinion. One famous example of this are the events leading up to the development and usage of the atomic bomb¹. During this era of nuclear development, physicists found themselves having to deliberate on how their research would ultimately impact the trajectory of a global war. It is in this large-scale view of their work that physicists must invoke some set of ethical reasoning skills to navigate morally ambiguous situations.

As of 2019, the physics community holds some awareness of physicists' ethical responsibilities. This sense of ethical responsibility is one that is shared with other STEM fields, that is, to deliver honest and true scientific work². The motivation for scientific work, often referenced by leaders in STEM fields and physicists, is for that research to have better and broader impacts. To ensure that research is honest and that it will indeed have a better and broader impact, researchers in any field must first be *able* to reason through the

complex ethical implications of their research. The importance of this ethical aspect of research is reflected in the resources made available by the American Physical Society (APS) which discuss issues regarding data acquisitions, plagiarism, and conflicts of interests. Resources for assessing the macro-ethical issues regarding complex social and political consequences of physics research remain rare.

This research calls attention to the importance of macro-ethical discussions in the physics classroom by presenting an analysis of how physics students engage with a curricular unit on the development of the atomic bomb. To do this, the research does not judge students' conclusions, but rather it focuses on *how* students arrive at them. We include the details of two studies conducted over the course of 2 years at the Physics Department at Texas State University. The first is a published analysis of student written work; the second is an analysis of group dynamics in the classroom. Our primary focus for this thesis will be to discuss how the group dynamics develop in class and how they develop in response to class set up and embodiment.

By presenting this research we are providing insight into what macro-ethical discussions can look like between future physics graduates and future physicists. We can think about what ways student discussions can be supported and guided. We can also begin to construct and accumulate resources for instructors interested in incorporating ethical discussions in their

curricula, and for students interested in learning ways they can assess ethical dilemmas that are potentially related to their work.

Research Questions

To begin understanding ways in which ethical discussions can be supported in the physics classroom, we conducted 2 separate studies. Study one focuses on student written work submitted at the end of a nuclear physics unit. Study two focuses on student in class discussions.

For Study 1 we asked:

- A. How do physics students interpret and apply an ethical framework to the development of the atomic bomb and other STEM examples?

For Study 2 we asked:

- B. How do physics students reason about large scale ethical issues in the classroom?
- C. How do specific instructional approaches support or limit this reasoning?

In the paragraphs to follow, we present a literature review, describe our method and analytical approach.

2. LITERATURE REVIEW

Ethics

Ethical standards are placed to enforce safe, humane, and professional research. Ethics provides a context for how to weigh most, if not all, of the important aspects of decisions that must be made. It can be described as how people deliberate what is good and bad, and what to consider in these deliberations. Broadly speaking, ethics can be divided into two subcategories of micro- and macro- ethics. As defined in engineering education research, "Micro ethics considers internal relations of an engineering profession" ³. An example of this in academia would be an advisor-student dilemma wherein the legitimacy and integrity of data is in question. A student may find themselves in a situation where their research adviser is not following codes of conduct and the student must decide how to proceed. They may fear what will happen if they expose this misconduct, whether they will graduate on time, and whether their entire research will be nullified. They could also consider the integrity of the research, and what it would mean to share false data with the rest of their research community. These are all issues directly associated with the individual and so this can be categorized as an issue of micro-ethics. Macro-ethics "...applies to the collective social responsibility of the profession and to societal decisions about technology" ³. An example of this for a student could be deciding which research project to join. If a particular research position would mean supporting knowledge that would eventually be used against a

group of people (for whatever purpose), this student must consider whether they are willing to work on that research knowing its intended purpose.

Similarly, a student may be offered a position to manage projects that are not mindful of their environmental impacts. The student may then want to consider ways they may approach their work that satisfies the demands of their projects while leading in a way that is environmentally considerate.

Ethics in Physics

Ethical conduct and its implications are already an integrated part of the physics research experience. When it comes to micro-ethics, violations of micro-ethical norms can reflect poorly on the entire physics community and erode at the public's trust in scientific work. Moreover, unethical behaviors towards colleagues can contribute to unhealthy work environments. The American Physical Society (APS), representing over 50,000 physicists in academia, national laboratories, and industry, has already acknowledged the importance and impact of micro-ethical discussions in physics. In 2004, APS created a task force that was charged with advising APS on "how it can best encourage physics departments to do a better job of educating students, postdocs, and faculty about scientific ethics" ⁴. One of the recommendations made by the task force was that APS create and maintain a website as a resource for ethics education. This website now includes case studies for both students and teachers to reflect on issues of publication practices, authorship, data acquisitions, and mentoring ⁵. As we explained, these are issues directly

associated with micro-ethics as they consider the interpersonal issues that may arise in a physics research setting. By enacting these recommendations, APS has invested in resources to help students, teachers, and physicists learn more about how to maneuver through discussions related to micro-ethics. Any physics students who find themselves facing a micro-ethical dilemma, or any teacher who is interested in teaching about micro-ethics, would likely go to this site and find these tools.

When it comes to macro-ethics, physicists must still consider the larger impacts of all aspects of their work. History shows us that personal values can influence how physics advancements are framed in the context of global power. During World War II, scientific research was strongly supported by government funds so that countries could establish dominance on the global stage ². Allied physicists and German physicists had to weigh the consequences of physics research when it was clear that the technology was evidently being weaponized. Physicists Lise Meitner and Max Born refused to work on such projects. Werner Heisenberg worked in efforts to support the German power. Niels Bohr and Robert Oppenheimer worked in efforts to support the United States out of fear that Hitler would conquer the world ². Each scientist had to weigh the consequences of their actions and their own ability to carry them through-by doing this the physicists were essentially practicing macro-ethical reasoning. Yet, the culmination of these decisions and events also

demonstrated how government funding led to significant technological advancements.

In this way, government contracting of scientists lead to a shift in how scientific research was funded. Government agencies supporting physical sciences, space science, environmental science, etc. were founded in the years after the war, creating a competitive arena for scientists. Most pronounced is the National Science Foundation (NSF), that was established in 1950 just following World War II. As part of its grants merit review, the NSF considers the “Broader Impacts” of an applicant’s work ⁶. Broader impacts include increased public scientific literacy and public engagements with science and technology, improved well-being of individuals in society, improved national security, and enhanced infrastructure for research and education. If physicists were to apply for a grant from an agency like the NSF, they would have to employ some level of ethical reasoning to assess the impact of their proposed work correctly and honestly. This process of framing motivation and purpose require that physicists use ethical reasoning skills to properly consider the large-scale impacts of their research. However, few resources currently exist for doing so. If the trajectory of physics students is to eventually be able to reason and make strong arguments for their work, as well as to make educated decision about their contributions to larger projects, resources and education must focus on developing macro-ethical skills. For these reasons, it is important to provide resources that extend beyond micro-ethical topics in physics.

Building on Engineering Ethics

While there is not much research in physics for macro-ethics education yet, we can refer to resources already available in a similar field. We begin to explore what ethical discussions can look like a physics classroom by building on literature already available in engineering. Due to the standards set by the Accreditation Board of Engineering and Technology (ABET), engineering departments around the globe include ethics as part of their required curriculum ⁷. This has prompted studies on approaches adopted by engineering programs to meet these standards. Common efforts to address ethics in these programs include stand-alone courses, modules within required courses, or a hybrid, which primarily draw from ethics codes and case studies. While these courses will often just focus on micro-ethics, there is an increasing effort to expand ethics education to include macro-ethics as well.

This push for ethics education has produced several different frameworks and models that describe different aspects of sympathy and empathy as integral for the development of ethical reasoning skills. Some researchers will focus on levels and stages for moral reasoning ⁸ as a way of mapping the progression of ethical reasoning. Others will focus on perspective taking skills, moral meaningfulness, and moral courage as indicators for ethical reasoning ^{9 10}. Others still will identify outside pressures that could influence students' abilities to act on their morals ¹¹ or that contribute to students' own sense of professional ethics ¹².

The ethics module that this thesis focuses on is guided by Hess, Strobel, and Brightman 's paper "The Development of Empathic Perspective-Taking in an Engineering Ethics Course"¹³. They focused on aspects of an engineering ethics course that contributed to changes in student's perspective taking skills and explored the nature of these changes. Perspective-taking was part of their larger conceptualization of empathy. In figure 1, we can see this conceptualization in four major parts. Empathy is depicted as either "self"-orientated, or "other" orientated. It can also be an affective experience where students experience an emotion such as distress or happiness, or a cognitive process where they can imagine emotions without actually experiencing them.

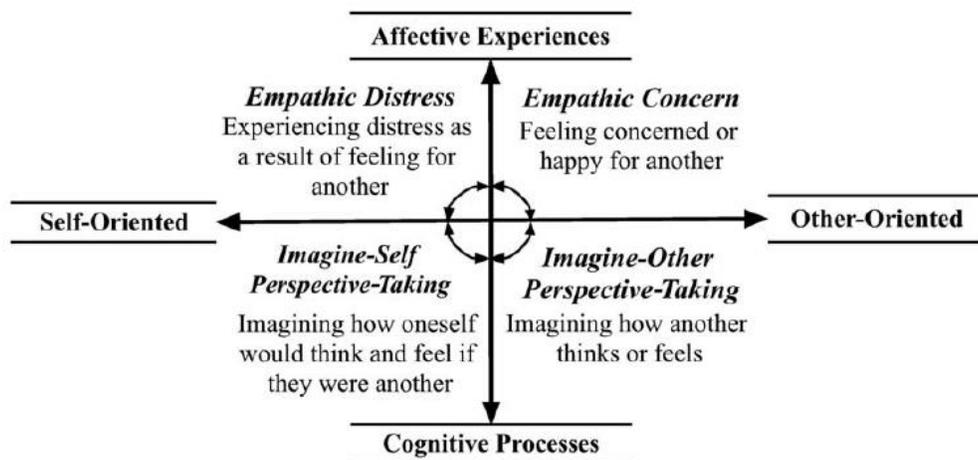


Figure 1: Conceptualizing empathy and the interrelationship between empathy ¹³

Perspective taking is a cognitive process of imagining the emotions of one-self or another under certain circumstances. In this way, Hess, Strobel & Brightman define perspective taking as "a cognitive component of empathy that is distinct from affective components but that is influence by affect".

Pedagogical & Ethical Frameworks

The pedagogical framework used by Hess, Strobel and Brightman was based on a SIRA (Scaffolding, Interactivity, and Reflexivity Analysis) framework. In this framework there are six stages, each with a learning activity varying in interactivity, scaffolding and reflection. Each stage is designed to help students' reason through case studies on related engineering projects.

- 1. Establishing knowledge: This stage has high scaffolding. Students are presented with the reference material to establish knowledge and foundation for their discussions. Students watch videos, read selected material, and/or post written responses
- 2. Perspective-Taking: Students reflect through writings and readings of stakeholders' perspectives. This stage is meant to be a reflective moment in the course. Students are tasked with identifying stakeholders affected by the cases they study, and reason from the stakeholders perspective, and/ or balance the stances of the different stakeholders.
- 3. Compare and Contrast: Students compare perspectives through moderated discussions. This stage is an interactive moment between lecture and students. Students compare and contrast their perspectives through moderated discussions on their findings.

- 4. Inducing Conflict: Students listen and read expert ethical and technical opinions. This stage introduces students to expert ethical and technical opinions through videos or assigned readings.
- 5. Decision-making and justification: Students debate through moderated discussion and collaborative writing. This is another interactive stage. Students participate in their second-in class session, and work within their team to respond to a case specific ethical question. They respond in a group case report.
- 6. Meta-reflection: Student reflect on their reasoning process through reflective writing. The reflection prompts require students to prioritize the ethical principles in the case context to rationalize their prioritization.

Mentioned as part of the course was the introduction and establishment of an ethical framework. The ethical framework used was that of Tom L.

Beauchamp's in his work titled "The 'Four Principles' Approach to Health Care

Ethics" ¹⁴. In this framework, the principle values are respect for autonomy,

non-maleficence, beneficence, and justice. Respect for autonomy is "to

recognize with due appreciation [a] person's capacities and perspectives". This

also extends to providing a person with enough information to make an

informed decision. Non-maleficence is "above all, do no harm". This is an

absolute avoidance of harm at all costs no matter what the reason. Beneficence

takes a more lenient stance where it is essentially taken as "maximize possible

benefits and minimize possible harm". Beneficence acknowledges that some harm may be done in order to help others and their interests. Justice in its simplest definition is "the minimal (formal) principle that like cases should be treated alike... or equals ought to be treated equally and unequal's unequally". Being the most controversial in that there is no specific way to define what "equal" is, justice is the principle that considers the distribution of both goods and rights as well as burdens.

Collaborative Learning in PER

While there is not much research yet specifically on macro-ethical education in PER, research on the students engaging in collaborative discussions can be used to build the foundation to support our research on the discussions that occur in the collaborative learning environments in this research. For example, Hammer, Elby, Scherr & Redish introduce the concept of "frame" and "framing"¹⁵. When an individual "frames", they are interpreting and contextualizing their actions and expectations. In essence, they are figuring "What is going on here?"¹⁵. The authors distinguish subsets of framing particular to different aspects of learning. There is epistemological framing where students set expectations for what they are to learn and how. There is also social framing where students set expectations for who they will interact with and how.

Scherr & Hammer use these concepts to study student behavior and epistemic framing during collaborative learning activities¹⁶. They focus on how students

approach tutorials by observing body language, eye contact, and other behavioral cues. These authors hypothesize what students expect for an activity by using students' observed behavioral approach. Scherr & Hammer propose different categorical modes of engagement that reflect different epistemological frames. They further highlight social framing as a key factor in the development of the epistemological frames. Students form expectations "for each other, of their instructor, and of themselves" and in turn these expectations influence the patterns of their group discussion. A group frame forms as a result of the collective interactions of individual students.

Scherr & Hammer share four distinct behavioral clusters that indicate separate relative group frames. The following table demonstrates the frames that embodies the behavioral clusters. They are sorted by color: Blue: worksheet Frame, Green: Discussion Frame, Red: TA frame Yellow: joking Frame.

BLUE: Worksheet frame		GREEN: Discussion frame	
<u>Behavior</u>	<u>Expectation</u>	<u>Behavior</u>	<u>Expectation</u>
Hands quiet, face neutral	Minimal interaction, individual activity	Prolific gesturing	Peers are watching and want to understand
Body leans forward, eyes on paper	Attention belongs on the worksheet	Animated tone, face	Intellectual and/or emotional engagement
Brief glances at peers	"Check-ins" expected	Sit up straight, eye contact	Attention belongs on peers
Read aloud without clarity	Peers coordinate, but read on their own	Clear, original speech	Peer interest in details of thinking
RED: TA frame		YELLOW: Joking frame	
<u>Behavior</u>	<u>Expectation</u>	<u>Behavior</u>	<u>Expectations</u>
Sit up straight; eye contact with TA	Attention belongs on TA	Giggle, smile, self-touch, fidget, unsettled gaze	Embarrassment, perceived vulnerability
Reduced gestures	Rehashing thinking		

Figure 2. Behavioral Clusters and expectations "likely to be associated with those behaviors" ¹⁶

We look to this material to support our analysis when we infer what kind of discussion and interactions students expect to have. For example, when students are approaching the worksheet, their behavior could be to sit quietly, leaning forward to keep their eyes on their papers, and briefly glancing at their peers. The expectation at this point might be that the group is focused on the handout and brief glances are, in essence, check-ins to see when other members are finished with the reading or ready to discuss.

Student Identities in PER

PER supports the idea that both behavioral cues and social framing can strongly influence student discussions. However, we must acknowledge that there could be other factors at play in students' discussions. We introduced the idea of social framing as a process through which students understand what is socially acceptable at the time. Students' level of engagement may also be influenced by students' interpersonal identities interacting with each other. Math Physics, and other STEM Education Researchers have all found evidence that identity statuses such as race, gender, and socioeconomic status significantly influence students' perceptions and interactions^{17, 18}. Systemic disparities do pervade in physics as they do in society¹⁹. For these reasons, it is important to be aware that there we can support our connections between behavior and framing, identity factors may also be at play in the development of collaborative dynamics between students.

3. STUDY 1

We note that this section is an excerpt from a publication in the 2019 Physics Education Research Conference (PERC) Proceedings and is included verbatim with minimal adjustments. As a result, some of the content is repeated from earlier in later sections. We note the authors as: Eglá Ochoa-Madrid, Dr. Alice Olmstead, and Dr. Brianne Gutmann.

Classroom Context

Students in this study were enrolled in a Modern Physics class during Spring 2019. The class included 23 students (36% women, 64% men; 50% white, 36% Hispanic/Latinx, 14% both Hispanic/Latinx and white), as well as three male instructional assistants (2 white, 1 Hispanic/Latinx) and a white female professor (the 2nd author). As part of a larger unit on nuclear physics (fission, fusion, nuclear stability, and nuclear ethics), students were guided through a 2-week discussion on the development of the atomic bomb. Student groups completed an in-class worksheet that asked them to establish a timeline of key events and people in the history of the atomic bomb development, and to consider Beauchamp's framework for ethical reasoning. Students were then asked to apply the ethical framework to letters and documents from key figures. Outside of class, students were asked to read Beauchamp's "Four Principles"¹⁴ and several letters from "The Manhattan Project: The Birth of the Atomic Bomb in the Words of Its Creators, Eyewitnesses, and Historians"¹ to build up their knowledge of relevant history and this ethical framework. On the

last day of the unit, students were asked to generate a list of current STEM examples to which the ethical framework could be applied.

Analytical Approach

We collected video-recordings of students' in-class conversations and documented their homework and exam responses during this unit. For this paper, we're choosing to focus on students' written responses to the following exam questions:

1. Consider a stance that a physicist or world leader took related to the development of the atomic bomb.
 - a. Describe the example that you are thinking of. Who took this stance? When were they thinking about this relative to other key events, and what was their alignment?
 - b. In what ways does this argument align with one or more of the four ethical principles that we have discussed in class? State the principles and explain your reasoning.
2. Provide an example of current scientific research to which the four ethical principles could be applied. What is an argument that someone could make for or against this research, and how does that argument align with one or more of the four principles?

Students' written responses to these questions seemed likely to demonstrate how individual students understand each of Beauchamp's four principles, and how they apply the principles to various situations. Responses to these questions also seemed likely to showcase some aspects of students'

perspective-taking skills. In our analysis, we look for trends in how students use each of the principles individually. We strive to foreground the ideas that students articulate before considering whether they used the “correct” terms to describe those ideas. We also strive to focus on how students’ reasoning helps them to build persuasive ethical arguments, as well as what limits these arguments. Although we did not observe this in our data, we left open the possibility that students could make persuasive arguments without using this specific framework.

Results

The table below shows the general trends we observed in student responses, including productive and limited applications for each principle. We elaborate on these trends below.

<i>Principle</i>	<i>Brief definition from [32]</i>	<i>Characteristics of productive applications</i>	<i>Characteristics of limited applications</i>
Respect for Autonomy	Enable stakeholders to make informed decisions	Describing how decision-makers share key information and seek others’ input before acting	Inaccurately describing how a decision-maker can deny/restrict others’ actions
Non-maleficence	Do no harm	Stating that harm will not be caused, or acknowledging possible harm and using nonmaleficence as a counter-argument	Using nonmaleficence to support and identify the benefits of a decision that involves possible or likely harm; conflating with beneficence
Beneficence	Maximize benefits, minimize harm	Identifying likely benefits of a decision; sometimes identifying likely risks	Omitting previously-identified stakeholders who could experience harm; not discussing potential risks generally
Justice	Treat equals equally	Identifying how benefits and risks could be distributed among specific stakeholder groups, and why	Using “justice” to be synonymous with the moral values or desires of a decision-maker (e.g., fairness, honesty, objectivity) without further specification of stakeholders; conflating with respect for autonomy

Figure 3. Beauchamp’s four ethical principles, along with observed trends of productive and limited student application. Note: Ref. 32 is the same as Ref. 1 for this thesis.

A. Respect for Autonomy

Essentially all students who use respect for autonomy seem to understand that it involves choice by stakeholders. Students who apply the principle

particularly well also seem to understand what it means to facilitate these choices. For example, one student applies respect for autonomy to consider how Einstein enable FDR and other members of Congress to make an informed decision about the atomic bomb:

"Einstein's advocacy... aligns with the principle of respect for autonomy...By encouraging communication between policy makers and scientists each group has more autonomy and ability to contribute to high-stakes decisions because they are all better informed"

Here, the student notes that Einstein enables FDR to make an informed decision by providing insight into the effects of the bomb. By doing this, the student considers the perspectives of Einstein and FDR as stakeholders in this decision. A second student considers Einstein's intention in writing to FDR when applying respect for autonomy. They write:

"Respect for Autonomy - [Einstein] wasn't forcing [the government] to act on his suggestions."

This student also recognizes that Einstein had at least some influence in how this decision was made. However, the second student's response also showcases a common point of confusion by stating that Einstein "wasn't forcing" anyone to act in any way. This limits the student's argument for Einstein's intentions in this context. Other students also describe Einstein and other scientists involved in the atomic development as "allowing" politicians to make their own decisions.

B. Nonmaleficence

Most students seem to understand that nonmaleficence stresses the importance of avoiding harm at all costs. Students who are particularly adept at applying nonmaleficence seem to recognize that this principle is absolute, in that no harm can be caused without creating inconsistency with the principle. One student strongly takes up this idea to suggest that stopping the development of artificial intelligence (until it is better understood) would prevent harm from biases:

“[A]pplications of deep learning algorithms have been known to have inherit biases from their data sets... the development of new technology in this area should be slowed down until solutions are arrived to prevent doing harm (nonmaleficence).”

In the context of their full response, this student cleanly articulates what the principle of nonmaleficence suggests as a decision path for the development of artificial intelligence, even while considering other decisions that prioritize beneficence.

However, there is evidence that students confuse the extent to which nonmaleficence means “do no harm,” instead interpreting it to mean “minimize harm.” This use conflates nonmaleficence with parts of beneficence. For example, one student states:

“FDR was pushing to create the bomb to maximize the benefits for his country and the allies... How is that bomb created without the intention

of evil? Simple. The U.S needed to show their "muscle" ... The bomb was deployed to stop the war. Wouldn't it have been evil to keep the war going?"

Like the previous student, this student recognizes the risk that their technology poses. They contemplate the creation and use of the bomb and how this came about "without the intention of evil" because ultimately it would stop the war. However, the student also describes deploying the bomb, which we, and likely the student, interpret as causing obvious harm. Instead of arguing that this stance goes against nonmaleficence by doing some harm, they argue that it aligns with nonmaleficence because it minimizes the "evil."

C. Beneficence

Most students reflect on both parts of beneficence: maximizing benefits and minimizing harm. The strongest applications of this principle also follow through on both ideas for multiple stakeholders and articulate a sense of prioritization. For example, one student states how FDR seems to have considered and prioritized the benefits to Americans relative to the harm to Japanese civilians:

"[FDR] would have rather obliterated the cities of Japan with the bomb than have risked the lives of potentially millions of Americans doing a land-based invasion. He was trying to do more good than harm... as he did have to weigh in the fact that hundred of thousands of Japanese civilians would have been killed. But this was for the benefit of saving U.S. lives."

Carrying this principle through in this way creates a consistent argument and demonstrate a thorough practice of perspective taking skills. In contrast, a different student, who considers the ethics of self-driving trucks, identifies truck drivers as stakeholders early in their response, but does not acknowledge them in their application of beneficence:

“Non-maleficence: Self driving trucks are smarter than human drivers and do not suffer fatigue... Beneficence: ...Producers will receive data on their trucks’ activity... Consumers will benefit from reduced insurance and liability.”

Here, the student does not acknowledge the risks of self-driving trucks to the careers of human drivers in their application of beneficence. This example also shows a pattern where some students avoid the negative aspects of beneficence.

D. Justice

There are a variety of approaches to applying this principle. Some students demonstrate a strong understanding of justice by describing how advantages and disadvantages are distributed among stakeholders. As an example, the student who writes about artificial intelligence presents the implications of biases in deep learning algorithms for justice:

“[T]his whole issue [of deep learning algorithms] rests on issues of justice, as one of the deepest worries is machines learning human biases from their data sets, which will unfairly harm several groups of people.”

Here the student considers that this technology has likely negative effects for certain groups, and explicitly connects this to the idea of justice. They note that because of the biases that artificial intelligence tends to inherit, the benefits will not be equally distributed. In contrast, other students do not discuss specific benefits and harms to stakeholders when considering justice. Instead, they apply justice in ways that seem tied to emotional responses and moral values. For example, one student takes Einstein's perspective as a refugee and describes justice as a reason he wrote to FDR:

"Albert Einstein wrote a letter to FDR informing him of the development of nuclear power where he tries to persuade him into gathering a team to develop this power before the Germans... Einstein was a refugee from Germany. He wanted justice from what Hitler was doing in Germany."

Along similar lines, multiple other students only invoke the word "fairness" in their description of how an argument aligns with justice. Another student evokes the moral value of objectivity ("providing objective facts and only the truth") to develop their argument for alignment with justice.

Finally, some students confuse the definitions of justice and respect for autonomy. For example, when a student is describing the ethics of gene editing, they write:

"Justice-> would those being tested on get all the information and risks?"

In expressing concern for informed decision-making, the student applies the idea of respect for autonomy not justice.

Discussion

We find that following a 2-week unit on the ethics of the development of the atomic bomb, most physics students demonstrate facility with at least one of the four principles in Beauchamp's ethical framework (respect for autonomy, nonmaleficence, beneficence, and justice) and can use them to construct meaningful arguments. Using this framework, students were able to identify multiple stakeholders and the perspectives they might hold. We also identify several limitations in students' applications of these principles. These limitations include conflating nonmaleficence with beneficence and justice with respect for autonomy; inaccurately interpreting respect for autonomy; focusing on only positive aspects of beneficence; and using justice to characterize moral values without specifying stakeholders. These results demonstrate that Beauchamp's ethical principles provide useful scaffolding for physics students to construct ethical arguments. Even in cases where students' reasoning is limited, we see the ideas behind the principles strengthening their responses. These results suggest that ethical frameworks generally may support student reasoning, and that it can be fruitful to adapt engineering ethics curricula for physics classes. This study represents an important step towards understanding how to support physics students in learning about ethics. It also opens up avenues for future research that could better diagnose the learning processes of students engaging with ethics curricula. In particular, video

analysis could provide valuable insights into why students construct particular kinds of responses, including potentially avoiding uncomfortable conclusions. We encourage others to build on this study to improve our community's understanding of how to incorporate ethics into physics instruction.

4. STUDY 2

Our goal is to understand how specific instructional approaches support and/or limit student reasoning through macro-ethical discussions. We start by building a model for understanding how a learning environment influences the classroom dynamics. We look to Sandoval's Conjecture Mapping approach²⁰. Sandoval introduces "conjecture mapping" as a means for specifying the features of a learning environment design and how these features contribute to learning outcomes. A conjecture map has four main parts: the high-level conjecture, the embodiment, the mediating processes, and the outcomes.

High-Level Conjecture

The high-level conjecture states how we think learning is happening in the environment studied. This statement should be supported by the rest of the map. Our high-level conjecture goes as follows:

Developing confidence and skills to engage in ethical discussions about the societal impacts of STEM requires practicing informed perspective-taking about ethical issues and learning to navigate differences in opinion among peers.

This high-level conjecture is what we hypothesize are the overall learning outcomes for this learning environment. While the learning environment is intended to have students practice informed perspective taking, our analytical focus is to learn how the learning environment influences how students navigate the differences of opinions in these discussions.

Course Embodiment

Next in our conjecture map are the embodiments. The embodiments are the features that define a learning environment. This includes worksheets, homework assignments, and classroom instructions, all of which contribute to the overall experience that the learning environment provides. The embodiments can be designed and changed over time with some control. Instructors can approach changes to curricula based on how students react and frame class prompts. Similarly, instructors also have the opportunity to pro-actively respond to students' framing in real time through simple embodiment features such as the language that the instructor uses to motivate a student discussion. There are also some factors that vary from implementation to implementation that are outside of an instructor's (or researcher's) control. These include students' prior knowledge, and students' own identities, that can influence the overall learning culture and environment.

The planned embodiments for this unit include:

- A macro-ethical situation relevant to a recent physics topic in the class.
- Facilitated learning in group and classroom discussions.
- A norm setting exercise.
- Introduction to an established ethical framework.
- A scaffolded perspective-taking activity.

- First-hand accounts from multiple perspectives, including stakeholders and decision-makers.

These are the controlled key features that we believe create and drive the students' learning experiences through the ethics unit.

Details of each of these embodiment features and others are described below.

Macro-ethical situation relevant to a recent physics topic. This particular ethics module was embedded on the latter half of the nuclear physics unit of a Modern Physics class at Texas State University.

Facilitated learning in group and classroom discussions. The class participates in a collaborative learning environment where they break out into groups and are supported by Learning Assistants (LAs) ²¹. In this class, students are accustomed to approaching class content in groups of 4-5 people. LAs routinely walk between student groups and interact with students by commenting or asking questions. The learning assistants in this study are former students of the modern physics class and their participation in the class environment is meant to facilitate student discussions. LA implementation is a facet of this course's key embodiment features.

Norm setting exercise. As part of the introduction to the nuclear unit, students participated in a norm setting exercise. This is a part of the embodiment that students have more control over and that also reflects some of the general values that they agree to uphold. This norm setting exercise

could potentially influence how student frame and anticipate the conversations to come in the ethics module.

Establishment of ethical framework & scaffolded perspective-taking. After the norm setting exercise, students continued to the nuclear theory learning fission, fusion, and nuclear stability. After discussing nuclear theory, students were introduced to the ethics worksheet that was modeled after the Hess et al. study. The worksheet-guided ethics module is structured in a similar fashion with a five-part guided discussion where students build a model timeline and framework and then apply them to historical resources and first-hand accounts.

- Part 1: Establishing key people and events: students create a timeline of major events related to the development of the atomic bomb.
- Part 2: Establishing a framework for ethical reasoning: students reflect on their understand of ethics and read an established ethical framework
- Part 3: Beginning the Manhattan Project: students consider the four principles in relation to letters written by scientists and politicians of the time.
- Part 4: Dropping the bomb: students discuss physicists' conflicting opinions about whether the U.S military should drop the atomic bomb on Japan.

- Part 5: Living with the bomb: students discuss the perspectives of physicists and politicians who continued to advocate for nuclear physics policies after the Manhattan Project had ended.

Firsthand accounts from multiple perspectives. First-hand accounts were provided to students through an online portal system. The first-hand accounts are sampled from “The Manhattan Project: The Birth of the Atomic Bomb in the Words of Its Creators, Eyewitnesses, and Historians” by C. C. Kelly and R. Rhodes. This is part of the embodiment that instructors can tailor based on what they wish to highlight from the experiences of the first-hand accounts.

Student demographics. While the instructor can plan the discussion prompts, and provide the resources , the instructor cannot control students prior lived experiences and perspectives that arise during the class. This is part of the embodiment that an instructor should be aware of as race and gender can influence the social frame that student adopt when engaging in ethical discussions. For this particular iteration of the ethics module, we had the perspectives of 23 students 36% of whom identified as women and 64% as men. The class was comprised of 36% of students who identified as Hispanic/Latinx, 50% of students who identified as White, and 14% of students who identified as both Hispanic/Latinx. Leading the class there was one white female professor, one male Hispanic/Latinx Teaching Assistant, and two male Learning Assistants both white and male.

Mediating Processes in the Classroom

After the embodiments, we build our mediating processes. Mediating processes are the conjectures that we make about the events and patterns that occur in student interactions. This is where we begin to focus our attention for what learning looks in our particular learning environment and where we gain insight on how to better support students.

Our three sets of mediating processes are:

- A. Distancing Spectrum: At one end, students use strategic distancing to speak about the decisions and intentions of certain stakeholders and decision makers. At the end, students use perspective-taking skills to assess stakeholders' decisions as they relate to the ethical framework.
- B. Complexity Spectrum: At one end, students express that the solutions, topics, and issues have clear and obvious implications, logic, and intention. At the other end, students approach their conversations with an acknowledgement of the complexity of the topic at hand.
- C. Group Collaboration Spectrum: At one end, one or two students are established as epistemic "authorities" and are more dominant in the conversation. This mode is coupled with a limited exchange of ideas between students. At the other end, all/most students in group have a more equal share in speaking about their thoughts and directing the flow of conversation.

We describe the mediating processes that emerged in this unit in more detail in our analytical approach.

Outcomes

From the mediating processes emerge the outcomes of engaging with this learning environment. We hope to improve the outcomes by assessing any changes needed to curricula through the embodiments.

Our desired outcomes are for students to experience:

- An appropriate application of an ethical framework
- A greater awareness of variations in peers' perspectives and values
- Feelings of validation on the importance of their ethical perspectives and concerns
- Increased confidence in navigating differences of ethical opinions

While we are presenting our outcomes, we are not exploring this empirically in this thesis.

Data Recording

On day one of the nuclear unit, I introduced myself to the class and shared the IRB approved protocols for recording and participation in the class. I made clear that participating or not participating in the study offered no reward and would in no way affect students' grade in the class. Students were informed that the unit and all of its components were part of the required curricula, and they were only providing consent to being recorded and studied for the research. Students were also made aware that knowledge of their consent was

known only to myself, and that their professor, who was also an investigator in the study, would not have knowledge of their consent.

I collected video data starting on the first day of the nuclear physics unit. There were two designated seating areas and another area specifically for students who did not wish to be recorded. The first camera captured one group of students during group discussions and students during class discussions. The second camera captured a second group of students; during class discussions, this camera recorded the instructor and whiteboard. A microphone was placed at each of the recording areas.

Students met every Monday, Wednesday, and Friday for 50 minutes of class time. Since the unit lasted for about two weeks, this resulted in a total of about 12 hours of recorded data for the semester.

Analytical Mediating Processes

With 12 hours of collected data we hope to understand the relationship between the mediating processes and the embodiments of the ethics module. We will be paying particular attention to Group Collaboration Spectrum. The group dynamics spectrum is centered on how freely ideas can be exchanged and discussed. We are interested in seeing how students engage with the class materials as they enact these different modes.

In our video analysis, we look for students' phrases that indicate what epistemological frame they have adopted. This includes phrases such as "The reading said to...", "I think we're supposed to ...", "They want us to...". We also

are watchful for non-verbal behavioral clues that indicate a sense for where student's attention is drawn to. We look for what direction students face their bodies to, when and where they shift their eyes to and ultimately what these body language changes are in response to. Similar to Scherr & Hammer, we hope to characterize modes of engagement but we further speculate how they may be influenced by particular characteristics of the embodiment.

5. ANALYSIS

Example 1

This example occurs on the fourth day of the nuclear physics unit and the first day of the ethics module. Before this discussion students had chosen “going to class” as their example for an everyday ethical example. The team had also agreed to write out the principles that align with the example on a white board in front of them as there was going to be a share-out later in the class time. The group agreed that writing down their responses to the prompt on the white board would be their approach. This allowed the team to see what they were agreeing to as Jaime wrote on the team's behalf; this set up the expectation or student's epistemological framing for how to approach the prompts.

Prompt:

Atomic Bomb Ethics II: Establishing a framework for ethical reasoning

2. Describe situation in your everyday life when you might choose to act in a certain way based the ethical implications of your action (or inaction). How would you decide what to do or not do? What advantages would you consider?

4. How do the four principles align with your own understanding of what ethical reasoning looks like? Do you notice any discrepancies between the ideas in the reading and what you think? If so, what are they?



Figure 4. Greg reads from the resources. Counter clock wise Amelio (left), Greg, Jaime, Amelio



Figure 5 The group is approached by LA Doug (off -camera) behind Greg and Jaime.

This group is comprised of 4 students. Counter-clockwise, they are Amelio (navy, long sleeve-left), Greg (long hair), Jaime (white shirt and watch), Guillermo (striped sleeves)

1. Dr. Halsey [Generally, to the class] So, just one quick thing. When you get to number four, when it's like how does this align with your

understanding of ethics, what I really meant to say was, take the example from number two and see if it fits with those principles - those four principles, but I don't think I actually wrote that in the question, so as you get there really think about, do these four principles align with the arguments that you're making in your example. {Jaime, Greg, Guillermo, and Amelio look to Dr. Halsey}

- 2.Jaime That's why ours wasn't as controversial because we picked 'going to class' {group laughs with Jaime}
- 3.Guillermo Well, it did say everyday life things. Like everyone in general {crosstalk} with Jaime}
- 4.Jaime Yeah, no. That's fine. We did good. Okay.
- 5.Guillermo It's not like we're seeing someone get murdered in front of us every day, or something. {Groups Laughs, except Amelio}
- {Jaime writes on the white board at the center of the table}
- 6.Greg Uhm.
- 7.Jaime That's what it says.
- {Greg begins speaking, Jaime turns towards him audibly agreeing, Amelio and Guillermo turn their heads listening on Greg and Jaime}
- 8.Greg Yeah, I know. I think our example is just pretty easily defined by these things. The only that would be questionable, would be the

first one. Because, if you're talking about the group instead of the individual, are you still looking out for their individual autonomy, or are you thinking of them more as one collective thing?

- 9.Jaime For ours, going to class, we're respecting our own individual liberty to choose not to go to class. We're not intentionally causing harm.
- 10.Amelio Unless it's to your grade.
- 11.Jaime {smiling} Well... yeah {crosstalk with Guillermo}
- 12.Guillermo ...to yourself yeah...
- 13.Greg I think it's implied that they mean to like ... {looking through papers}
- 14.Jaime Hurt or...
- 15.Greg People or things that matter.
- 16.Amelio Degrade something.
- 17.Greg Yea. If you're okay with your grade not being as high as it could be, then I don't really think that could be...{trails off while searching through the reading; the rest of the group looking to Greg waiting for him to continue}

- 18.Greg {reading} Do not kill. Do not cause pain. Do not disable. Do not deprive of pleasure. Do not cheat and do not break promises. So, as long as you haven't promised anybody...
19. Guillermo So, you make a promise, I'm going to class tomorrow.
- 20.Greg Yeah, if you're getting super financial aid, and it's dependent on you then that's a promise, and you are doing harm. {leaning back in his chair}
- 21.Guillermo Yea, that's true, because I think financials 2.5, or something like that?
- 22.Amelio It's 2.0.
- 23.Jaime It also depends. Because, on mine {looking through his papers} going to class, and where it says 'how would you decide what to do and what not to do', I just put those little things like 'Am I a group member?', and then if no, blah, blah, blah. But if yes, then here are the things I need to weigh on...
- {Learning Assistant Doug is off camera and approaches the group from behind Jaime and Greg. The group turns their attention to Doug as he speaks.}
- 24.Doug Would you say you're thinking a bit more how it affects others than yourself kind of way? Because going to class, I feel like, mostly the benefit or harm, is done towards the person that doesn't go. You did bring up a good point. If you're in a group,

and you don't go, you're not contributing to that, so therefore you're harming others, in a way. But ... {crosstalk with Greg}

25.Greg That's specifically what I put. I feel like going to class isn't a moral inherent, ethical enough issue to this kind of detail. So, I put you're either a leader or a part of a group. Whether or not you're going to class or not.

26. Doug Yea, that make sense. Because you're adding stakes to it. I personally don't see not coming to class as I feel like shit when I go and do that because I'm {crosstalk with Greg}

27.Greg But that's not an ethical {crosstalk with Doug}

28.Doug Well to me it feel like I... I ethically feel like a bad person for not going to class.

29.Greg Interesting {reclined in his chair}

This exchange shows a collaborative discussion dynamic where all members of the group contribute to the development of an idea discussed. There is flow between statements made from students as they adopt similar tones of discussion and react synchronously to each other whenever an individual is about to speak. This can be inferred from student's turning their bodies and/or gazes towards the speaker. We see that all members of the group respond to cues and accept bids made either from their environment or from members of their group.

Professor Halsey draws the groups attention by addressing the class to correct the prompt on the worksheet [Line 1]. This correction serves as a cue for students to check their responses. Greg, Jaime, and Guillermo verbally agree that their chosen example addresses the question and that it is an ethical everyday example. Here students seem to agree on what their example accomplishes [Lines 2-5]. This also suggest that the students all agree on how their example aligns with the principles. Jaime continues to write on the whiteboard. This allows the group to see what they are agreeing to as a team. Greg's audible reaction to what Jaime writes suggests disagreement with what was written [Lines 6]. Greg's reaction serves as bid for the group to discuss the details of what Jaime has written. Jaime responds to defend the writing, suggesting that it is directly supported by "it" [the reading] [Line 7]. This prompts a collective reaction from the group in the form of body language that indicates anticipation for what Greg will say. Greg expresses a detail of possible discrepancy in a way that can be interpreted to mean that he is asking for clarity from the group [Line 8]. The group then collectively builds a response.

Jaime is the first to respond and states the individual as the priority in their example and adds the idea of harm at the end of his statements [Line 9]. Amelio then implies that one can do harm to oneself by not attending class because it can ultimately affect your grade; Guillermo and Jaime agree to this addition [Line 10-12].

The group then inquires about what it would mean to do harm with respect to the "individual" who does not go to class and that stakeholder's concerns. Greg looks to the reading material for clarification and Guillermo reconciles the reading with their example [Lines 17-19]. Having the resource on hand allows Greg to immediately reference and gain clarity from the reading. Greg agrees with Guillermo's statement and adds that financial aid is kind of promise. This makes receiving financial aid a priority to consider given the definition the group just read [Line 20]. Guillermo and Amelio then contribute the GPA requirement for receiving financial aid [Line 21, 22]. Greg and Guillermo have verbally agreed that there is a contractual promise of attending class for financial aid and individual can do harm by not going to class. This suggests that students are considering class participation as part of the grade which eventually can drop to below the criteria and harm the "individual". In this example, Greg and Guillermo have chosen the individual student as the primary stakeholder and they are taking their concerns as a student receiving financial aid as the added element needed to understand what type of harm the individual would inflict if they chose not to go to class. They have narrowed the scope and details of their "everyday" example and used the definition of non-maleficence to do so. Most of the group appears to agree on how an individual can respect their own autonomy, but harm themselves by not going to class [Lines 9-22].

Jaime adds to the complexity of the example by explaining how he personally navigates the stakes and harm in the example through a “yes-or-no” logic map [Line 23]. He suggests that there are other factors that could be weighed in making a decision about going to class. The first of these factors that he mentions is ‘Am I group member’. This suggests that there are details to the example that Jaime is also thinking outside of the ones that the group mentioned. This adds to the discussion an alternative approach to reasoning about the everyday example. This displays a level of comfort between the group members that allows members to share their different approaches and ultimately creates a collaborative dynamic.

While the group was not allowed an opportunity to respond directly to Jaime’s approach, Doug’s questioning and thoughts afterwards draws out from the group the differences in the individual approaches. Doug asks about who Jaime is considering for harm [Line 24]. He offers a nuanced idea to the discussion but asking essentially about the priorities about who is being harmed. As we saw early in the conversation, most of the group centered the priorities of the “individual student”. We can infer from Doug’s question that he is trying to illuminate Jaime’s attention to the direction of harm in the logic map.

Greg responds to Doug’s statement through which he suggests that their example is simple and doesn’t need to be thought about “to this kind of detail” [Line 25]. We must take note of this moment as Greg does not realize that the

group has already discussed “this kind of detail” in his group. There is a point of reflection afterwards when Doug says that he feels “like a bad person for not going to class” [Line 26]. While we cannot say that Greg has changed his mind about this example, we can conclude that Doug’s expression was enough to prompt a moment of thought from Greg.

Example 2

This discussion occurs on fifth day of the Nuclear Unit and second day of the ethics module. Greg and Jaime are from the same team before in Example 1.

Prompt:

Part III: Beginning the Manhattan Project:

- 1. Consider the reading titled “Enlisting Einstein” and the subsequent letter that Einstein wrote. What was the main argument made by Einstein and his Colleagues?*
- 2. How does this argument align with the four principles (respect for autonomy, non-maleficence, beneficence, justice)? Which, if any, principles did Einstein consider, and how?*



Figure 6 Jaime reads writes on the white board. Counter clock wise: Greg (left) Christian, Nathan, Jaime.

This group is comprised of 4 students. Greg and Jaime accompanied by Nathan and Christian. Counterclockwise, they are Greg (long-hair), Christian (Nike Cap), Nathan (front facing cap), and Jaime (writing on whiteboard).

- 1.Christian Is there like and actual statement where he says 'yes, I am for the atomic bomb'?
- 2.Jaime No. Not in this letter. In this letter his recommendations are:

{Jaime begins reading from his paper. Greg and Christian sit towards him; Nathan writes}
- 3.Jaime "to approach government departments, keep them informed of the further development, and put forward recommendations for government action, giving particular attention to the problem of securing a supply of uranium or for the United States

B. To speed up the experimental work, which is at present being carried on within the limits of the budgets of university laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German, under secretary of state, Von Weiszacker, is attached to the Kaiser-Wilhelm Institute in Berlin where some of the American work on uranium is now being repeated."

{Greg leans into Jaime, Christian leans and begins writing, Nathan remains watching and writing}

4. Jaime So his recommendations are: A. to make sure government departments are informed about it and then also to provide... to speed up the experimental work that's happening with this.
5. Greg So, beneficence is definitely there.
6. Christian Yes, I agree.

- 7.Greg Because he's trying to benefit the administration and the war effort ...
- 8.Nathan And also, to an extent, talking about how it could be a really good source of energy.
- 9.Greg Sure. He doesn't say that this will only be used for bomb. That's not... he does say that it'll be used for bombs but.
- 10.Nathan I think he understood that it was inevitable that people would try to make an atomic bomb.
- 11.Greg Sure. {Group returns to writing}
- {The professor approaches the group from off camera next to Greg and Christian}
- 12.Professor Greg, you're making an argument that Einstein was going for beneficence, right?
- 13.Greg Yes.
- 14.Professor So, I guess I'm curious where some of that, Beneficence is the maximize good, minimize harm one right?
- 15.Greg Well. So I...We defined them slightly differently. I kind of agree with that definition. But we, at least I, thought that the second part of that definition was really close to non-maleficence. So like we separated the two even more then the class wanted to. So we said non-maleficence. We said it's ... The reason they're two different things is because you can not-do-harm and not-do-

good at the same time. Like you could do nothing. Because they're two different points, you have to consciously decide that you're not doing harm and consciously decide that you're doing good. So, I was arguing that non-maleficence is it there because he is recommending them use, or at least, he is recommending then use a power source that he later says would be used to make bombs.

16.Christian {Quietly} Mhm.

17.Professor So, it's not non-maleficence because you're creating nothing that can do harm.

18.Christian {Quietly} yeah.

19.Greg But I {crosstalk with Jaime}

{As Jaime begins speaking, Greg and Nathan lean in and turn towards Jaime. Christian writes and mumbles to himself occasionally}

20.Jaime Only reason why I disagree that is because it's the argument. And yea, what he is saying up here is a part of this letter but that's all statements. It's not 'do this or do that'. And whenever you go to the argument part, which is supposed to be... like an argument is to persuade someone... And this persuasions or recommendations are speeding up the experiments that's

happening and then also keeping government departments informed.

And that's like my only reason why I don't think... That's the reason why I think his argument does align with non-maleficence because he's not bringing harm; he's not bringing instruction. Yes. What might've ended out of this research is the atomic bombs but his arguments were never create a bomb or to do this or that. It's just to keep the government departments informed and to do research.

{As Jaime finishes, Greg, Nathan, and Christian lean back to their chairs}

21. Professor So, you're arguing his non-maleficence because he's not saying to use the bomb or to even necessarily [inaudible]

22. Jaime {nodding} Mhm.

{The group turns to the professor. Christian returns to writing and mumbling to himself}

23. Professor I don't know that there's necessarily a correct answer to this one. We don't know exactly what Einstein was thinking. I think that they're both legitimate. As long as you're sort of able to understand what those different principles mean and how they apply to this argument. It's okay to have a little bit of disagreement.

24.Jaime Mhm {nodding the group returns to writing; Professor walks away}

25.Greg Did y'all know there's different style omelets?

26.Christians Yeah, for sure. People go crazy for omelets. '

This exchange also shows us a collaborative dynamic. Throughout the exchange the group employs similar body language and tone indicating a uniform adoption of the social frame between students. This social frame is essentially "we can build on an idea, and we listen and turn to the speaker". The epistemological approach seems to be uniform for the team in this mode as well. The group looks to the reading to assess their response. While there are differences between the details of the examples that individual students share, the expectations seem to be that as a group they will not explore these details. Members either don't address the differences or attempt to reconcile the differences in the examples. Later, Professor Halsey serves as and is draws out the difference between Greg and Jaime's arguments just by questioning the students.

Christian starts the discussions by asking for a particular line from "Einstein's Letter" [Line 1]. Jaime reads directly from the source and highlights that he is reading the recommendations. The group collectively leans in to listen, except Nathan who looks up and looks down to write periodically. This suggests that

the collective expectation at that moment is for the group to “listen”. Jaime’s next words summarize the recommendations made by the author [Line 2-3].

Next, we see again that there are differences in the details for the arguments that the group members make. While these discrepancies are potential avenues for discussions, the team does not pursue them. Greg is the first to start and sets the focus on Beneficence [Lines 5-7]. Nathan adds to Greg’s point to which Greg reacts with by trying to reconcile his argument with Nathan’s [Line 8, 9]. Nathan states plainly that there was an undeniably harmful potential in developing the technology to which Greg only replies with “sure”. The group returns to writing [Line 10, 11]. The group does not contest the different thoughts between Greg and Nathan. Greg attempts to reconcile both and ultimately just agrees. The group keeps going; this is the expectation. In this way, the group exhibits no sign of tension and is agreeable.

Professor Halsey acts as cue for discussion on the different opinions about which principle actually aligns best with the argument made in the letter. [Line 12] It is unclear when Professor Halsey walks up to the group, but when she approaches, she asks Greg to clarify his statements on beneficence. [Line 15] He explains that he defined beneficence and non-maleficence differently from the class. Greg’s understanding of non-maleficence and beneficence includes the intentions behind the action. His argument is that Einstein’s intended purpose was not to explicitly ban bombs, so the argument is does not align with non-maleficence. Professor Halsey re-states Greg’s argument back to the

group [Line 17]. While Christian seems to agree with Professor Halsey re-iteration of Greg's statement, Greg attempts to elaborate before Jaime jumps in [Line 18, 19]. Jaime reacts to the statement by saying that he disagrees. Jaime's approach focuses the recommendations made in the letter and explains that it isn't about intention but about what is being argued for. Jaime highlights a point he stated previously in this example that there are recommendations that Einstein advocated for. His argument is that Einstein advocated for increased development of nuclear technology but that it was never to create the bomb [Line 20].

Greg and Jaime explaining their own understanding of how the principles apply to the argument induces from students (at least Greg and Jaime) to approach the discussion differently. They each have a different approach but elaborate more on their discussions than before they were approached by the instructor. Professor Halsey restates Jaime's argument [Line 21]. She also clarifies that there is not one clear possible answer so that both Jaime and Greg's arguments are valid.

As Professor Halsey leaves, student continue writing and completely switch the topic of the conversation [Line 25, 26]. Students showcase a similar approach to the rest of their discussion where they do not pursue difference in their opinions after they are stated.

Example 3

The following transcript takes place the second day of the ethics unit. Students have been introduced to ethical framework and are now discussing part III of their Ethical Discussions Worksheet. The prompt goes as follow...

Beginning the Manhattan Project:

3. Consider the reading titled "Enlisting Einstein" and the subsequent letter that Einstein wrote. What was the main argument made by Einstein and his Colleagues?
4. How does this argument align with the four principles (respect for autonomy, non-maleficence, beneficence, justice)? Which, if any, principles did Einstein consider, and how?



Figure 7. Counterclockwise: Jasmin with water-bottle (left), Kevin, Alexa, Grant, Emily.

This group is comprised of 5 students. They are Elize (white striped shirt), Grant (solid black shirt with glasses), Alexa (solid black shirt), Kevin (blond hair), Jasmin (red shirt).

Previously the day before, the group was comprised of Elize, Alexa, Jasmine, Kevin and another student who was not present during this discussion.

Students arrived at the topic of war, why it happens, and what is “fair” to target in war. Students have just had a discussion on the civilian lives lost during war. There is a serious tone to the conversation.

1.Alexa I don't know, why do we fight war? Why can't we all just be peaceful coexistence? {swinging in her chair, looking around; Emily and Jasmin smile}

2.Grant Because France and the Treaty of Versailles decided {crosstalk with Kevin}

3.Kevin Well if you figure it out, let us all know

4.Grant ...to take almost two thirds of all arable land from German, restrict them from the air

{Emily, Jasmin, Kevin, and Alexa return to look down at their papers}

...took all their mines, limited their ability to build a military presence. And then within a couple of years their economy crashed, and they didn't have enough food.

5.Alexa {scrunching her nose laughing towards Grant} It was rhetorical, Grant. {Jasmine, and Emily smile while looking away from the table}

- 6.Grant if Germany didn't declare war and start expanding their nation was going to die.
- 7.Alexa True. {Alexa quietly looks down to her paper, Emily, Jasmin, and Kevin return to their papers}
- 8.Grant War is sometimes necessary especially when you don't have the resources. I mean, are you going to let your nation die before you decide to go out and find some food? How long do you let yourself starve before you decide to eat?
- 9.Kevin I'd think about it. {The group looks to Kevin. Alexa laughs, Jasmin nods and smiles}
- 10.Grant Well they waited a while. They let the mark fall pretty low until Hitler came around and then nationalized them.
- 11.Alexa Which is the one that they say is...Is it beneficiaries where they say maximize the benefits, minimize the ... I think here they were thinking about maximum amount of benefit for the country would be to drop the bomb... {Alexa is looking at her documents, crosstalk with Grant}
- 12.Grant That's a fair argument.
- 13.Alexa ...according to their argument.
- 14.Jasmin What did you say [Alexa]?
- 15.Alexa Beneficiaries because that one is about maximizing benefits and minimizing harm?

{Alexa looks towards the group, Jasmin and Emily nod, Alexa continues writing}

I think that's the what they thought. That's the only way to end the war is a nuclear bomb.

16.Grant {Grant takes his phone out} Also, I think assassination falls under legal warfare. To your point, your ethical use of dropping the bomb would be to drop the tiniest bomb ever to kill the emperor of Japan, which would qualify as an assassination.
{Emily sits up and looks away, Alexa slowly rises and turns her head towards Grant}

17.Alexa I wouldn't want anybody to do die. {Jasmin nods}

18.Grant Not even Hitler? {still looking at his phone}

19.Alexa {quietly} I don't know. {Jasmin and Alexa laugh together}

This example shows students negotiating for the general approach to the conversation. The conversation is tense and sometimes awkward as ideas do not flow freely in the discussions. Grant holds control of the conversation through long-winded responses that limit when and how other students can engage ultimately influencing the expectations of the group. The group's over-all body language is indicative of these expectations as most of the time group members are looking down at their paper reacting mostly to Alexa. The group's over-all body language is indicative of how engaged they are in the conversation when Grant or Alexa are speaking.

Alexa introduces a light-hearted tone to the conversation that Grant had previously guided into a serious argumentative tone [Line 1]. Emily and Jasmine react to her by smiling in her direction. Grant and Kevin both respond to Alexa [Line 2-4]. Grant responds to Alexa's question in a tone that suggests a serious approach to her question. While Kevin also responds to Alexa's question in a joking matter that reciprocates her light-heartedness, Grant continues to speak over him. Grant's response continues in a serious long-winded fashion and the rest of the group looks down at their papers without responding [Line 4]. The drop in energy and engagement from the rest of the group indicates that the group doesn't intend to respond or comment.

Alexa drives the negotiation through bids for a change in the social and epistemological frame. Alexa scrunches her nose, and laughing, turns to Grant and makes clear that she wasn't expecting a "serious" answer because her question was a rhetorical one. Jasmine, and Emily sit up and smile as they face away from the table [Line 5]. Jasmine and Emily's reaction to Alexa is a flash of energy and acknowledgement at Alexa's bid to change the tone of the conversation from a serious one to a more light-hearted one. Grant does not seem to acknowledge Alexa's comment/bid and continues [Line 6]. Alexa seems to resign and quietly responds with "true" [Line 7]. Jasmine and Emily follow suit and also return to their papers.

After, there is another sort of bid made on Kevin's part to change the tone of the discussion which Emily, Jasmine, and Alexa appear to accept. Grant

continues his speech on war which pauses at a question [Line 8]. This time, Kevin responds to this question in a similar fashion as before in line 3 [Line 9]. Alexa laughs and Emily and Jasmin smile. Grant seems to acknowledge Kevin's response but keeps his more direct tone about the discussion [Line 10].

There is a switch the conversation when Alexa directly changes discussion by drawing attention back to the principles. This is effective in focusing the discussion back to answering the prompt. Alexa directly switches the topic of the conversation by asking about one of the principles and how it would align with the argument. As she finishes Grant speaks over her to agree [Line 11-13]. Jasmin asks Alexa to repeat her previous statement. Alexa restates her point in tone that suggests that she is insecure about her claim. She is reassured when Jasmin and Emily nod, then she finishes her thought [Line 14-15].

While the group seems to now focus on the principle, Grant pressures Alexa. As Grant takes out his phone, he makes the claim about Alexa's supposed argument [Line 16]. We say supposed as Alexa has made clear that it was "their" argument - the authors' argument. [Line 16 - 17] Alexa seems to be taken off guard by Grants suggestion that she argued for assassination and slowly rises to quietly respond [Line 16-17]. Grant pressures her argument by offering an infamous target of assassination for speculation. Alexa responds quietly then seems to make eye contact with Jasmin and they laugh together [Line 18-19].

Example 4

Prompt:

Atomic bomb ethics, part IV: Dropping the bomb

Once the atomic bomb had been developed, physicists had conflicting opinions about whether or not the U.S military should drop the bomb on Japan. In this section, we'll consider two conflicting statements from physicists written at around the same time.

4. How do the arguments in the Science Panel report align with the four ethical principles? Which, if any, principles do they consider, and how?

5. In what ways do you agree with the arguments made by authors of the Frank report and/or the Science Panel? Who do you agree with more? Who do you disagree with?



Figure 8. Alexa shares for iPad with LA Doug (off-camera).

This discussion occurs later in during the same class period as example 3.

- 1.Grant {speaking generally in no particular direction} How can Japan pay close to no cost for their war crimes just because they had a nice island close to Russia. So, then we just made buddy-buddy and forgave them for everything.
- 2.Alexa Not everything. There is Japanese concentration camps in the United States.
- 3.Grant yea but they were nothing like what they were doing over there.
- 4.Alexa Yea but still {crosstalk with Grant}
- 5.Grant Japan started World War 2 by invading and enslaving all of Korea and rest of eastern Asia ... {Alexa and Emily look in front of each other, Jasmin continues looking down at iPad}
- 6.Kevin Yea...Yea {nodding in agreement} {in between Grant's sentences}
- 7.Grant ...They were raping them, killing them. I grew up in Jeju (presumably South Korea). The island was two-thirds female because they killed so many males and the population hadn't bounced back yet. {Emily stretches and reclines back looking away. Kevin nods. Alexa flips through her papers}
- 8.Alexa Isn't that the case for a lot of places in Europe? Where the population hasn't recovered from World War 2, right? {Alexa looks furrows her brows looking across to Jasmin and Kevin}
- 9.Grant I believe it.

- 10.Kevin I can see that being the case.
- 11.Alexa Right? I feel like it's either that or the plague or famine.

{Speaking to Kevin} One of them where the population {crosstalk with Gran}
- 12.Grant I can't imagine the plague as having a major [crosstalk with Alexa]{Alexa turning sharply to Grant}
- 13.Alexa Not the-the famine

{Alexa turns to Kevin} Somewhere I read that the population hasn't recovered in certain areas after World War 2 because of the deaths. But I... {Alexa caves in and extends her fore arms away from her}
- 14.Grant Generally, the population bounced back. The gender differences because these things are normally targeted to one gender. Because after you get a massive amount of death like that, the population spikes enormously. But the problem is you can't make up for all the males that are dead... {out to the group, Jasmin Alexa and Emily are looking down at their papers}
- 15.Kevin Right. {Kevin nods}{crosstalk with Grant}
- 16.Grant ... so then you have this huge disparity of females and unfortunately {Emily begins to play with her hair...}

It's hard to reproduce with... {Alexa looks over to Emily}

- 17.Alexa {laughing} Just going to go quiet?

{Emily hides her face, Jasmin smiles looking at Alexa and Emily"

There's a back. It says, 'which do you agree with more' Frank,
Frank, Frank. I agree with Frank more. {The group flips their
papers over}
- 18.Grant Or the science panel. So, we have to argue {crosstalk with Alexa}
- 19.Alexa It's a personal question, like what ways do *you* agree with...

{Grant sits up in his chair}
- 20.Grant In personal, I don't take an apathetic approach. I don't approve
of it. I take it all the time, but I don't approve of just saying 'I
don't know'. {Ends in a mocking tone}
- 21.Alexa I'm against it. I take it with Frank. F-R-A-N-K. {Hunching her
shoulders as she spells out 'Frank', crosstalk with learning
assistant Doug}
- 22.Doug {Off camera behind Jasmin and Kevin}; at the same time with
Alexa} I mean, that's an easy stance to take...
- 23.Emily {quietly, glancing at Alexa} That's how I feel too.
- 24.Grant I don't think unilaterally...What do you think is the easiest stance
to take? {looking off-camera}

In this example, we see there is more negotiation within the group. Grant continues to hold influence over the conversation through the same means of

longwinded and superfluous statements that limit other students from responding and from being acknowledged.

Grant claims that Japan paid no cost for their war crimes [Line 1]. Alexa offers a counterclaim by suggesting that the Japanese concentration camps were a form of “cost” [Line 2]. Grant minimizes Alexa’s point by suggesting that the concentration camps were not nearly as severe as Japan’s crimes and continues to support his argument while speaking over Alexa [Lines 3-5]. Grant continues with a lengthy elaboration where half-way through Alexa and Emily make brief eye-contact before returning to their papers, Jasmin continues to look down at her iPad, and Kevin vocalizes in agreement [Line5-7]. The groups body language suggests that they are not expected to comment or engage with Grant.

Alexa also drives the negotiation however this time, there is bidding for a change in the epistemological frame by using cues from the prompt. Alexa again tries to bid for a connection between her peers and the conversation when she attempts to connect to Grant’s comment of his own personal experiences to the aftermath of Japanese invasion [Line 7,8]. Alexa looks to her group for a connection which is indicated by her expression and her turning her body when looking to her group. Grant and then Kevin accept her connection as a possibility and Alexa continues by expressing that she isn’t sure whether it is famine or plague related but directs specially towards Kevin [Lines 9 -11].

Alexa again tries to guide the discussion to be more inclusive and shows signs of frustration when Grant speaks again. As Grant begins to express that he doesn't believe that a plague could have as big of an impact, Alexa sharply turns to him and cuts him off and turns to Kevin [Line 12, 13]. She starts off strong in her argument but then caves in indicating that she is not confident in her claim [Line 13].

With a slight pause, Grant begins another lengthy comment on targeted gender disparities. Kevin is the only one in the group to respond, vocalizing his agreement with this statement [Lines 14 -16].

Alexa soon attempts to negotiate the groups focus through the question prompt. Alexa calls attention to what seems like a disengaged Emily who has now started playing with her hair. Emily appears to be caught off her guard and shyly hides her face, and Jasmine and Alexa smile and laugh. Alexa points out that there is a prompt question that asks students about which stance they agree with [Line 17]. The entire group then flips their papers over to see the question that Alexa has pointed out. Grant speaks again with an intrigued tone vocalizing his expectations for the prompt. That is that they (the students) "have to argue" [Line 18]. Alexa interrupts grant, to highlight that it is a personal question and emphasizes the word "you" in the prompt [Line 19]. Grant immediately jumps in, sits up in his chair, and speaks again to answer the prompt out loud [Line 20]. Alexa states plainly that she sides with Frank and then sings as she spells out his name [Line 21].

It is not clear when Doug approaches the group because he is off camera behind Jasmin and Kevin. He speaks at the same time as Alexa to say that "that" is an easy stance [Line 22]. Emily glances over to Alexa and quietly agrees. It is not clear which statement she is agreeing to [Line 23]. Grant seems to start a thought and then directs his gaze to what we assume is Doug (off-camera) to ask what stance they take [Line 24]

6. DISCUSSION

Study 2 demonstrates the emergence of a group dynamic spectrum. I define the group dynamic spectrum by how students share and build ideas. In this section, we justify the characteristics of two group modes in that dynamic spectrum. We also discuss the advantage and disadvantages of each and where they present themselves in the data.

Study 2 demonstrates the emergence of a group dynamic spectrum. These results are not meant to represent the experiences of all physics students. This pool is too small. I would rather consider this as a snapshot into what was happening in this classroom at that moment.

Collaborative Mode

Our first group mode is the Collaborative Mode. The collaborative mode is defined by a collective clear epistemological and social framing agreed upon by students. The group acknowledges and follows bids and cues for discussion. The group members are agreeable and there are little to no perceivable awkward or tense moments. We see this group mode emerge in Example 1 and Example 2 of our analysis. As we see in Example 1, all or most members of the group will react in a similar fashion. They also all attempt to address bids or acknowledge cues for discussion. When Professor Halsey makes her address to the class it serves as a cue. Jaime and Guillermo are the first to comment on their example, to which the group responds positively by laughing. The group collectively continues writing; that is something that the

group did together. When Greg bids for clarification [line 8], the group builds a discussion to address it [lines 9 -22]. When LA Doug approaches the group, most of the group also pauses to listen to his exchange with Greg [line 24 - 29]. The conversation has encompassed ideas from all members of the group in varying degrees, but each students' contribution helps propel the details of the conversation. In this way, the collaborative mode emerges in example 1.

Example 2 exhibits similar moments further justifying the Collaborative Group Dynamic. In this example, students work together to agree on a principle that aligns with the resource that Jaime had just read outload as a way of answering Christian's question [Line 1]. While there isn't a line exactly like the one that Christian had asked for, Jaime reads the question. Then, Jaime summarizes the recommendations, Greg identifies a principle and Nathan and Greg attempt to build a uniform answer [Lines 1-13]. After being approached by Professor Halsey, the group returns to their papers and soon Jaime talks about omelets. While this is random, Greg does not contest Jaime's comment and accepts it for conversation in an agreeable fashion [Line 24- 26].

The collaborative group mode enables group members to offer bids and to have those bids acknowledged. This facilitates the flow of ideas and increases the possibility that students will be exposed to different perspectives and understandings of the ethical problem and values. However, the collaborative mode can limit discussion if students fall under the expectation that they must reconcile and agree on all of their responses. In example 1, the group all

agrees on the example that they've chosen. Even when Greg makes a bid to discuss what's been written on the white board, he makes the statement that their example "is just pretty easily defined by these things" [line 8]. The group then focuses on the principle that Greg highlighted and build a response for it. Jaime begins to offer a different perspective on the reasoning when LA Doug approaches. Greg then expresses his own interpretation which is congruent to Doug's comment. While the team was building a collective response, they glossed over the details of how the other principles were related to their example and did not probe any farther.

In example 2, we see more evidence for the way that an "agreeable" approach can hinder the development of ideas. Greg focuses the discussion on beneficence and the group agrees. He expands his statement by explain why Beneficence "is there". Nathan offers another perspective that is different from what Greg just stated [line 10]. Greg says "sure" and makes two attempts to reconcile his own statement with Nathan's additions [Lines 8 -11]. In this discussion, we also see Jaime only expanding on his perspective for why the principle aligns when Professors Halsey approaches the table. This is evidence that groups in the collaborative mode can limit their own expression ideas to follow a more "agreeable" trend of conversation.

Negotiation Mode

Our second group mode is the Negotiation Mode. The negotiation mode is defined by a series of bids for different epistemological and social framing of

the conversation. We see this group mode emerge in Example 3 and Example 4 of our analysis. As we see in Example 3, Alexa expresses a bid for a more joking and light-hearted approach to the discussion. She starts with a whiney toned question out loud [Line1]. Kevin and Grant both respond but in different tones, one which jokingly compliments her tone, and another which offers a serious response to her question [Line 2-3]. As Grant continues to speak, there is no room for any other comments or acknowledgments as he dominates the moment and in turn the group sits in silence until Alexa offers another bid. She expresses that her questions were merely rhetorical and because she is laughing, and because she also receives a response from Kevin, Jasmine, and Emily, we can deduce that they may have accepted the bid. However, Grant creates tension in his group by continuing to speak in the group space [2-10]. Alexa switches the conversation to the prompt as she looks through the resources [Line 11]. Grant acknowledges and agrees with Alexa's statement while Jasmin asks her to repeat herself [Line 12-13]. It may seem that the group could accept Alexa's bid to now focus on the principle that relates to the reading. Grant makes an extended comment pressuring Alexa's response. The group is silent. Alexa seems to be caught off-guard by Grant's assertion and laughs with Jasmin (possibly as nervous response) [Line16-19]. Grant is the primary driver of the conversation, and Alexa seems to negotiate on the rest of the group's behalf. The collective understanding seems to be that Grant will speak and the rest of the group will listen and write independently.

Example 3 exhibits similar “bidding” moments for the focus of the conversation. Grant begins with a question out loud. Alexa offers a counterexample to what his question implies but her argument is effectively minimized by his continued argumentative tone [Line 1-7]. Alexa attempts to connect with note on population in Grants claim which also serves as a bid when she looks to Kevin for reassurance. Grant, again, attempts to minimize the argument, but Alexa attempts again to engage Kevin by cutting Grant off and turning to Kevin [Line 7 -14]. Grant begins with another long-winded claim that the Emily, Jasmine, and Alexa respond to again with sitting quietly and looking down at their papers. It isn’t until Alexa draws attention to Emily who is now playing with her hair [line 17]. She highlights a part of the worksheet that asks students about their personal alliance with the different resources they read about. It is at this point that we see a clear bid, and clear vocalization of expectations for the discussion. As Grant attempts to frame the prompt as an “argument”, Alexa emphasizes that the prompt specially says “you” as way of drawing personal approaches and therefore the prompt does not ask for arguments [Line 17-19]. Grant is the first to respond “in personal” ending in mocking tone [Line 20]. Alexa then plainly states her take ending in a sing-songy spelling of “Frank” [line 21]. While Emily quietly voices that she “feels” that way too, Grant draws in the LA into the conversation. In this way, we see how negotiations are made by bids through the prompts, and tone by members of the group.

The negotiation mode limits student's engagement as there is no clear way to express ideas in a way that they will be acknowledged and accepted for discussion. As we see in example 3, Alexa is the primary driver of the negotiations in her group. She uses comic relief to relieve some of the silence that the group experiences while Grant dominates the conversational space. She receives some response from the rest of the group mates, but there is still no change in their level of engagement, and the ideas do not develop past what Grant contributes from his own personal knowledge. Similarly, in example 4 Alexa again attempts to draw in her teammates into the discussion; this time expressing slight frustration and being more assertive [line 11 -13]. Alexa even attempts to bid by specifically quoting the prompt to emphasize that it asks for students' personal stances [line 19]. This happens directly after calling out Emily's silence which, in essence, reflects the group's expectation. Examples 3 and 4 showcases how the negotiation mode limits the flow of ideas.

Supporting Group Dynamic Modes

The pitfalls of Collaborative and Negotiation modes can be helped through the different embodiment features. This is because embodiment features can be used as cues and for bids by groups to help detangle details of discussions as well as create more room for various group members to speak. The embodiment features that were used as bids and cues in our four examples are: 1. Professor and Learning Assistant Check-Ins. 2. Access to White-Board/

Shared Spaces. 3. In-class Access to Source-Material. 4. Specific Prompt Language

Instructor and learning assistant check-ins. Professor Halsey and Learning Assistant Doug walking through the class and approaching the group offer an opportunity for students to voice their opinions with the challenge of being clear in their arguments. In this way, students express their ideas out loud and in front of the group. As in Example 1 [Line 24, 25] and Example 2 [Line 15 -23], an instructor or learning assistant prompts students to voice their opinion if it is different from one mentioned or noticed by the instructor. This may be in part due to an expectation that who-ever speaks, speaks on the group's behalf.

Access to whiteboard and shared spaces. In Example 2, The whiteboard was as a shared space where the group could create a physical representation of their shared thoughts and conceptualization. As we see in Figure 5, the white board offers the opportunity for different members to pick-up a marker and add to whatever is already present. This is an embodiment feature that was used as a bid for conversation. Whiteboards as a shared group space also have the potential to help students elaborate on a collective idea.

In-class access to source material. Groups were able to reference source material as they were answering the worksheet prompts. While not all

students had printed copies like Jaime and Greg in examples 1 and 2, students still had access to the source material online through their smartphone or iPads like we see in Figures 7 & 8. The ability to quickly read and reference source material offered another bidding tool for students to propel discussions and to negotiate.

Prompt language. The language adopted by prompts can be highly influential in setting up expectations for student groups. The language can indicate to what kind of responses are appropriate and how responses should be supported. As we see in Example 4, the prompt can be used as a bid to change the group's current approach to the discussion.

7. CONCLUSION

It is evident that in the current social-political landscape professionals in STEM communities are being held to higher ethical standards. As part of the larger STEM community, physicists must also follow suit and be able to reason about the implications of their status, influence, and work. This means that they must understand ethics and what ethics would mean within the context of physics as a field.

Resources on how physicists can learn about micro-ethical dilemmas exist and are currently accessible online. This thesis is a call for attention to the fact that close to no research and support exists for physicists to learn how to reason about macro-ethical dilemmas. The work presented in this thesis provides insight into a possible avenue of support. We conducted two separate studies to see how physics students engage in an ethics module focused on a macro-ethical dilemma within the context of a larger nuclear-physics unit. With these studies, we can formulate ideas about what supporting physics students reasoning about macro-ethical issues can look like.

The studies conducted looked at data from one modern physics class taught at Texas State University but focused on separate aspects of the embedded ethics module. Study 1 focused on the written work presented by students during a final exam. These results demonstrated that the "Four Ethical Principles"¹⁴ provide useful scaffolding for physics students to construct ethical

arguments. While students could build strong ethical arguments, they were still prone to conflate ethical principles and avoid discussing negative implications of scientific advancements.

Study 2 focused on video-recorded data of student's in-class discussions. We discussed 4 example clips that showcased 2 separate modes of engagement. The first mode was the collaborative mode demonstrated by students when communicating ideas freely and easily. Students also exhibited signs of "agreeableness" that limited whether they would expand on discrepancies in reasoning. The second mode was the negotiation mode. Students demonstrated conflicting approaches to the conversation that ultimately limited the exchange of ideas. It is important to note that these modes of engagement are presented with the intent to offer a glimpse of what occurs as students engage with the ethics module. We don't intend to suggest that one mode is better than the other as we hope to support students with whatever they bring to class. Both of these modes were influenced by features of the class that served as cues or avenues of possible pivot points in their discussions

We see guided instructions and prompt language can be useful cues and tools for students if they want to expand on a topic or change the flow of the conversation. It may also be fruitful to provide a common space for students to share within their groups. This would allow them to write out ideas that are representative of what the group agrees to. Instructors looking to support

similar emergent groups in an ethics module may consider incorporating these embodiment features to help groups avoid the pitfalls the students in this study encountered.

While Study 1 and Study 2 offer some insights to the way that this ethics module can support students ethical reasoning, they only provide a snap-shot of what students discussions look like in this physics classroom. These studies do not offer a large enough pool of participants, or enough data to represent student experiences and learning macro-ethical reasoning skills across all physics classrooms. Our studies show us what is possible and provide avenues for further development of ethics curricula. I encourage other physics educators and instructors to use these studies as a starting point for their exploration on supporting ethical discussions. Moreover, future research could explore the extent to which ethical discussions truly impact physics students approach to their practice, and what ethical models are best suited for future physicists and scientists. A more ethically minded physics community would be better prepared to face the complex issues that will arise from an increasingly interconnected and diverse global society.

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