Development of an Interactive Guide Aiding Senior Capstone Project Students in Ethical Analysis

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Submitted to:
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Abstract

At Worcester Polytechnic Institute (WPI), the completion of a Senior Capstone Project is mandatory for undergraduate Biomedical Engineering (BME) students. The project plays a crucial role in addressing and assessing ethics and healthcare disparities within the BME curriculum, however, there is no sustainable approach to guide students in completing the ethics component of their project. To address this issue, we developed an interactive guide that was integrated into the Canvas learning management system (LMS). The interactive guide consisted of modules aimed to guide BME students in writing a complete ethics statement that identifies and mitigates ethical concerns related to their capstone major-qualifying project (MQP). The interactive guide was pilot-tested and iterated based on feedback from participating students and advisors, and then implemented for all MQP groups to use. We also developed a rubric to score previous MQP ethics statements and compare them to ethics statements created using our interactive guide. The rubric scores of ethics statements improved significantly in groups that used the interactive guide. Furthermore, feedback received from students in surveys indicated that the interactive guide was successful in guiding students to consider ethics and healthcare disparities in relation to their project. Based on these findings, we recommend the interactive guide as a sustainable and permanent solution to better prepare students to identify and mitigate ethical concerns related to their projects.

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Executive Summary

Introduction

A thorough understanding of ethics is a critical piece of undergraduate BME education, both to meet the Accreditation Board for Engineering and Technology's (*ABET Accreditation*, n.d.) criteria for ethics knowledge and to train ethical scientists at undergraduate institutions such as WPI. One such place where ethics must be considered is the Senior Capstone Project completed by all undergraduate students at WPI, known as the Major Qualifying Project (MQP), but past years' MQP reports (*Major Qualifying Project*, n.d.) show weak engagement with ethics topics. This project was designed to incorporate a curriculum specific to the BME Senior Capstone so that students could deeply consider the ethical implications of their MQP projects and be prepared to do this type of critical thinking throughout their imminently approaching careers. This timing is especially key as students at this phase have a concretized idea of professional commitments and job experience. In addition to ethics criteria, BME students should also be able to make critically informed decisions on the impact of projects and decisions on healthcare disparities, as their undergraduate education and future careers are most likely involved with healthcare. This curriculum aided students in more deeply analyzing and considering avenues for mitigating potential ethical issues that arise in their projects.

Methods

The interactive guide was created through Canvas, a program already implemented by WPI for coursework, to guide BME MQP students in creating a complete, thoughtful ethics statement that also considers healthcare disparities. The interactive guide is self-guided to allow for autonomous implementation and include prompts to guide an accompanying ethics discussion with the student's MQP advisors. The modules conclude with the students creating a

comprehensive ethics analysis that can seamlessly integrate into their MQP paper and presentation, which is a requirement for all MQP reports.

A rubric was created with the help of Doctor Yunus Dogan Telliel to score ethics statements from past years and test the effectiveness of the interactive guide. MQP ethics statements from 2021-2022 MQP reports formed the basis of the prior year comparison for this project. Pilot groups then completed the online ethics course and provided their ethics statements, which were scored using the rubric and compared to previous years' scores. Feedback from both the advisors of the project and students who completed the online ethics course was used to improve the modules. After incorporating feedback from pilot groups into the interactive guide, improved modules were then introduced to the whole BME MQP class for the year 2022-2023. The ethics statements created by the full participation class were then scored and compared to previous years' and pilot groups' scores to assess whether the modules were successful in preparing students to produce higher-quality ethics statements in their MQP reports.

Results

The average score for the prior year ethics statements (n = 33) was 3.6 out of 20 possible points, with a standard deviation of 3.3. The pilot groups for this study (n = 3) scored higher, with an average score of 10 points out of a possible 20, with a variation of 4 points. The pilot groups and advisors reported that they benefited from the interactive guide and their scores show improved ethics understanding compared to prior years. Ethics statements submitted after iterative improvements (n = 23) received an average score of 8.9, with a standard deviation of 4.35.

Discussion

The project was limited by its timeline, since most BME MQP students were unprepared or unwilling to complete an ethics statement earlier in the academic year, which was when the pilot phase occurred. This left little time for a second iteration of the interactive guide before implementing the program across the entire BME MQP cohort. The project was also limited by the ethics knowledge of the BME MQP advisors, as their knowledge was crucial in making the Advisor-Advisee discussion critical and generative. It is recommended that students complete the interactive guide in the earlier stages of their MQP projects, but finalize their statements closer to completion of the final report. Further, advisors are encouraged to participate in their own ethics education, such as a separate ethics module specifically for advisors, to better guide those discussions with advisees. Another recommendation is to iterate the interactive guide with the help of more stakeholder feedback gained from additional pilot groups closer to the end of the academic year. Feedback gained during this time would be more helpful since students would be able to complete the ethics statements at a time more convenient for their project when they are more likely to be able to dedicate time to crafting a thoughtful ethics statement.

Conclusion

In conclusion, this project produced an autonomously functioning educational module and generative tool for producing in-depth ethics statements to meet ABET requirements for BME MQP reports. Based on the rubric produced, ethics statements created using the interactive guide scored higher and met more ABET requirements than ethics statements created in the prior year without the interactive guide.

Introduction

At WPI, students who graduate from the BME department have possible job trajectories including the medical field, the medical device industry, the pharmaceutical industry, and industrial and academic research. Through their training and project-based learning at WPI, BME graduates are prepared to pursue careers with wide implications for the wellbeing of people and society. However, this potential for impact makes it addedly necessary to conduct research in a responsible, ethical manner. Biomedical engineers design instrumentation and devices which will be used by surgeons and practitioners on a wide variety of people who do not look like themselves. In this way, they are forced to make decisions that impact both their own world and the world of others. One such implication of ethical decisions engineers make is for healthcare disparities, in which a certain group receives poorer quality and/or access to healthcare and medical procedures.

Undergraduate institutions are concerned with developing ethical thinking in their students as part of a robust education, but although ethics education is a priority for many universities, incorporation into engineering education proves difficult. Part of the career preparation that every WPI graduate experiences is their senior capstone project, the MQP. The ethics statements required within their final MQP report is a critical benchmark for demonstrating that they can not only conduct ethical science, but think critically about their own work and how it fits into the broader world around them.

Given that there is no formalized training or guidance to aid students in this portion of their MQP, this project sought to evaluate the existing quality of these statements and develop a training guide to help MQP students think more deeply about the ethics of their MQPs and aid them in producing high-quality, critical ethics statements. The interactive guide includes an

introduction to ethics and health disparities for students unfamiliar with the concepts, an example statement for comparison of what was done well and what can be improved upon, as well as resources for a guided Advisor-Advisee discussion on the ethical considerations of the students' capstone project. All these components aim to help students write an ethics statement that considers the unforeseen impacts that biomedical developments may have on the world.

Literature Review

Ethics Overview

Ethics guides people to make moral decisions and is needed to assure that people, animals, the environment, society, and cultures are kept safe and preserved in a conscious manner (Resnik, n.d.). The Markkula Center for Applied Ethics at Santa Clara University (Vasquez et al., n.d.) has developed an integrated framework for understanding ethics. This group includes twenty-five ethics scholars and practitioners in many fields including Ph.D. ethicists, lawyers, businesspeople, educators, religious leaders, scientists, and journalists. This group made up of people with vast backgrounds and various perspectives investigated the principles of ethics, which are the standards of right and wrong that direct humans on what they should do in terms of rights, obligations, benefits to society, fairness, or specific virtues (Vasquez et al., n.d.).

SCU describes many misconceptions regarding ethics, one being that most people describe ethics in terms of their feelings, even though feelings often deviate from what is morally right. Others use religion when making ethical decisions and instead rely on the principles of said religion. Most religions advocate for high ethical standards, yet if ethics were confined to religion, then ethics would only apply to religious people. Another misconception is that being ethical means following the law, but, like feelings, laws can deviate from what is ethical. Finally, being ethical is not the same as doing what society accepts, since standards of behavior in society can deviate from what is ethical.

After clarifying these misconceptions, ethics is defined as both well-founded standards of right and wrong that direct people on what to do in terms of rights, obligations, benefits to society, fairness, and specific virtues, as well as the study and development of

one's ethical standards, including feelings, laws, and social norms (Vasquez et al., n.d.). Furthermore, ethical standards include rights, such as the right to life, freedom, and privacy (Vasquez et al., n.d.).

Applied ethics, or practical ethics, defined as, "the application of ethics to real-world problems" (*Applied Ethics - Ethics Unwrapped*, n.d.) is concerned with various ethical issues throughout a multitude of fields, with branches including medical, business, and engineering ethics. Applied ethics uses ethical theories to form a sound position on a given situation. The difference between applied ethics and basic ethical theories stems from the solutions of applied ethics being more narrowly focused and specific. Applied ethics provides solutions to ethical dilemmas by reviewing the facts of a specific situation rather than broader moral theories, making applied ethics a perfect way to have engineers decide on ethical decisions since they do not have a solid background in ethics or ethical frameworks. This branch of ethics does not require engineers to master ethical frameworks before applying them to their work.

Healthcare Disparities Significance

The quality and access to care that patients receive can vary wildly within the healthcare system, whether intentional or not. The Agency for Healthcare Research and Quality (AHRQ), is the federal agency that works to improve the safety and quality of healthcare for Americans (*Disparities | Agency for Healthcare Research and Quality,* n.d.). AHRQ develops the knowledge, tools, and data needed to improve the healthcare system in America in order to help consumers, healthcare professionals, and policymakers to make informed health decisions (*Disparities | Agency for Healthcare Research and Quality,* n.d.).

According to AHRQ, healthcare disparities are defined as "differences in access to or availability of medical facilities and services and variation in rates of disease occurrence and disabilities between population groups defined by socioeconomic characteristics" (*Disparities | Agency for Healthcare Research and Quality,* n.d.). Some of these socioeconomic characteristics that can influence healthcare access include race, ethnicity, age, sex, gender, education, geography, economic status, etc. Cynthia M Jones, PhD. who is an associate with the Pan American Collaboration for Ethics in the Professions and a professor at the University of Texas connects healthcare disparities and ethics by describing that healthcare disparities are morally wrong while ethics provides theoretical justification for viewing healthcare disparities as morally wrong (Jones, 2010).

One example of a healthcare disparity can be seen in the 2022 National Healthcare Quality and Disparities Report published by the AHRQ. It was revealed that compared to non-Hispanic white populations, Hispanic populations received poorer access to medical care for 73% of measures of access to healthcare (*2022 National Healthcare Quality and Disparities Report*, n.d.). It was also shown that the access to care for populations in large central metropolitan areas was poorer for 64% of measures of access to healthcare, as compared to populations in the suburbs. Many socioeconomic characteristics identified in the report reveal similar disparities in care (Morden et al., 2021). A study of 2016 and 2017 Medicare claims data revealed that black patients were far less likely than white patients to receive opioids. According to the study, the mean annual dose of opioids was 36% lower for black patients than for white patients (Morden et al., 2021). Another example of healthcare disparities is how language barriers can greatly influence understanding between patients and doctors, negatively affecting patient satisfaction and outcomes (Shamsi et al., 2020). In order

to address these issues, larger healthcare institutions have implemented interpreter services to improve healthcare access, patient satisfaction, and communication, however, these services increase the cost and duration of the visit (Shamsi et al., 2020).

These disparities can arise from a number of sources. Biases from healthcare providers, misdiagnoses within certain patient populations, and even exclusion of populations from medical research can negatively affect patient care, widening disparities. For example, economic factors such as health insurance coverage may limit what care the patient can reasonably access and could potentially disincentivize the patient from seeking out healthcare in the first place. Additionally, provider psychology can play a pronounced role in the quality and availability of care to certain populations. A systematic review from PLOS ONE concluded that feelings of racial supremacy and stereotyping of minority patients as poorly behaved impacted the quality of and access to medical treatment (Sim). When healthcare disparities arise in a minority population, they negatively impact the population's quality of life, and while it is not the only factor, it can contribute to a general disparity of health and well-being.

Healthcare disparities are not the only factors that impact the overall health of minority populations. The 2022 AHRQ National Healthcare Quality and Disparities Report identified 5 key social determinants of health: education access and quality, economic stability, social and community context, neighborhood and built environment, and healthcare access and quality (*2022 National Healthcare Quality and Disparities Report*, n.d.). Health disparities caused by social determinants other than access to healthcare can also play a role in expanding disparities in the healthcare system. When populations are affected by healthcare disparities, they may create an increased burden on the healthcare system and

indirectly affect the availability of healthcare services to themselves and/or other demographics.

Current State of Ethics and Healthcare Disparities Education in BME

Ethics and healthcare disparities are important concepts for any healthcare professional to consider since many biomedical engineers end up working in healthcare. WPI defines biomedical engineering as, "a learned profession that combines expertise and responsibilities in engineering, science, technology and medicine" (*BME Code*, 2004). Many BME students enter the workforce with jobs related to medicine and healthcare, whether that be in the medical device industry, biomaterials, or working directly with patients. WPI suggests an ethical code that all BME students must follow, "since public health and welfare are paramount considerations in each of these areas, biomedical engineers must uphold those principles of ethical conduct embodied in this code in professional practice, research, patient care, and training" (*BME Code*, 2004).

The code states that students should fulfill professional, healthcare, research, and training obligations including being moral and conforming to confidentiality and legal agreements. BME students at WPI need to be prepared to enter the workforce and learn about the various ethical principles that must be considered when working in the field of biomedical engineering, and be aware of the healthcare disparities that may arise.

Currently, at WPI, there are multiple standalone ethics courses that can be taken by any WPI student, regardless of major. Some of these courses include Bioethics (PY2713), Ethics (PY/RE2731), Philosophy and Ethics of Computer Games (IMGD2001), and Leadership, Ethics, and Social Responsibility (OBC 4367). WPI only requires robotics

engineering (RBE) majors to take an ethics course (Social Implications) while all other engineering degrees are not required to take any ethics course (Bushe et al., 2022).

There is no formal course focussing on healthcare disparity education at WPI, however, there are a number of prior Interactive Qualifying Projects (IQP)—interdisciplinary projects that are a degree requirement for all WPI students—that have made strides towards increasing the quality and presence of healthcare disparity education in the BME Department. In the 2021-2022 school year, members of the Educating about Healthcare Disparities IQP identified an absence of healthcare disparities education in BME curriculum, despite the majority of interviewed students feeling that the subject was “very important” (Bushe et al., 2022). In order to increase knowledge of healthcare disparities among BME undergraduates, the project group created educational modules for courses at all four levels of the curriculum and recruited BME faculty to deliver the modules both in a live-classroom and asynchronously. The project group also gave the students of recruited faculties’ classes pre and post-surveys to study the effects of completing the module on students' knowledge of and appreciation for healthcare disparities education. Post-module surveys showed that for each grade level, at least 67% of students felt confident that they could give a definition and example of each given subset of healthcare disparity. Despite the majority of the surveyed students agreeing that an educational health care disparities module should be required within the BME curriculum, after implementation, no changes were made to add a health care disparities or ethics requirement to the curriculum. Additionally, once the project ended the group members were no longer encouraging faculty to utilize the modules, and without formal requirements, there was little incentive for faculty to integrate the modules into their already packed curriculum.

A project completed in the prior school year created a similar lecture presentation to be presented in BME courses as well as providing a case study in which students role-played as healthcare providers to help identify potential biases and ethical concerns (Cordner et al., 2021). The lecture presentation identified five separate causes of healthcare disparities: Western bias, demographic bias, skewed research populations, implicit bias, and inconsistent and erroneous medical diagnosis. BME students were also educated on the fundamentals of healthcare disparities, examples of disparities, and associated ethical theories. This project found that relative to survey results taken before administering the module, a higher proportion of students reported comfort levels of somewhat comfortable or higher with regard to their understanding of ethical theories. After the module, a higher proportion of students were also able to define key healthcare disparities terms such as the five causes of disparities. However, this project's members felt that WPI's fast-paced learning environment and 7-week term system made it difficult to integrate an extra 50-minute lecture into an existing class's lecture time. The lecture content created during this project has also not been implemented in a WPI class since the project's end, and no changes to the curriculum requirements were made as a result of this IQP.

While a number of IQP projects including the two listed above have attempted to add ethics and healthcare disparities into WPI's BME curriculum, very few have succeeded in long-term implementation. It is clear that without changes to policy or curriculum requirements, it is difficult to integrate educational models into classes that are operating under such small margins of error for timing, and even more difficult to convince faculty to adopt the changes permanently.

Outside of WPI, a number of universities across the country have provided biomedical engineering students with opportunities to learn about healthcare disparities and potential ways to address them. Educators in the Department of Biomedical Engineering at The City College of New York (CCNY) conducted a multi-year study in which Health Disparities modules were provided at all levels of coursework, as well as creating opportunities to focus on health disparities within undergraduate research projects and capstone design projects (Vasquez et al., 2017). At the end of the study, an increase in both knowledge and awareness of health disparities was observed for BME students who participated. Georgia Institute of Technology implemented a similar health disparities module into mid-year BME coursework, with an emphasis on fostering empathy for those affected by disparities (Nezafati, 2020).

As described, other universities are educating BME students on ethics and healthcare disparities, and after concluding that further education on ethics and healthcare disparities was needed at WPI, we attempted to find a class in their education at WPI that all BME majors must complete. After considering different class options, we concluded that in order to reach all BME students, an ethics and healthcare disparities curriculum should be implemented during their Major Qualifying Project (MQP) project, which must be completed in order to graduate.

Worcester Polytechnic Institute (WPI) requires all students to complete an MQP. As WPI defines it:

> "The MQP, a team-based, professional-level design or research experience, makes the answer a very positive one. The culmination of WPI's project-based undergraduate education, a successful MQP demonstrates such learning outcomes as how to communicate effectively; understand the scientific, societal, and ethical dimensions of

the problem; and demonstrate knowledge appropriate to your specific major. And every year the results show students finding meaningful work" (*Major Qualifying Project*, n.d.).

This project is typically completed during a student's final year at WPI, which was an important factor when determining where to include further ethics and healthcare disparities curriculum for BME students. One advantage of incorporating this curriculum during their final year is that by the end of their time at WPI, BME students have a specific disciplinary focus and more applications to the real world. Additionally, by their final year, most students have completed internships or school projects sponsored by companies specific to their field which gives them more perspective on real-life issues.

BME students must create ethical statements regarding their project in order to partially fulfill the Accreditation Board for Engineering and Technology (*ABET Accreditation*, n.d.) requirement for ethics. ABET is a program that accredits college and university programs, in the disciplines of applied and natural science, computing, engineering, and engineering technology at the associate, bachelor's, and master's degree levels. With this accreditation, WPI students and employers can be confident that WPI meets the quality standards that produce graduates prepared to enter a global workforce (*About ABET*, n.d.).

The main qualifications that constitute a good ethics statement for MQP projects at WPI are based on ABET requirements. The main requirement that the BME department at WPI uses to assure all projects meet ABET qualifications is as follows (*ABET Accreditation*, n.d.):

> "(4). An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts."

A strong ethics statement considers all ethical standpoints and comes to a sound conclusion that considers the impacts of the project's actions in the future and plans to mitigate them. In this section of the paper, environmental, global, societal, and economic factors should all be fully considered. For each of these categories, students should identify any current ethical concerns along with future ethical considerations, and mention how to mitigate potential ethical issues. Students should also consider the costs and benefits of their project, from all standpoints, in order to make informed judgments about the ethical concerns of their project. Ethics statements should also include how healthcare disparities may arise and how they can be mitigated in relation to the project.

Existing WPI BME MQPs and Project Types

Previous BME MQP ethics statements do not meet every aspect of the ABET requirement listed above, which is required in order to be considered complete ethics statements. When looking at ethics statements from BME MQP papers from the year 2021-2022, most statements did not make an informed judgment on any aspect of the ABET requirement listed above. Environmental and societal factors were often considered, but only some groups also touched upon either global or economic effects. Past MQP reports included short, separate statements about each ethical consideration: global, economic, environmental, and societal. Using a short paragraph style meant the statements likely lacked depth and it

was suspected that they were not long enough to have informed judgments on the ethics of all aspects of their project.

According to WPI, their MQP projects "lets you solve real-world problems and challenging research issues that might be similar to what you will find in your professional life" (*Major Qualifying Project*, n.d.). Though WPI students usually do not get further than the research or prototyping stage of their ideas for their MQP projects, they should consider how their device would be used in the real world and the ethics behind those decisions, in addition to the ethical implications of the work they are able to do during their projects, which pushes students to make informed judgments. Modeling a real-world environment means that students should be concerned about every stage of their project, from research and prototyping to testing, marketing, and maintenance. Each of these stages has its own unique ethical considerations for teams to reflect on and decide on a course of action. Emphasizing implications found in future implementation and marketing of an MQP project allows project students to think about how their devices may contribute to or lessen health disparities.

A surface-level examination of ethics related to health disparities during MQP research would consider how "expanding healthcare access, data collection, and the use of evidence-based interventions will contribute to health equity for vulnerable populations that are defined by income, geography, disability, sexual orientation or other important characteristics" (*HHS Action Plan to Reduce Racial and Ethnic Health Disparities*, n.d.). Past MQP ethics statements often kept in mind the populations considered during research, but few went on to make informed judgments anticipating how populations would be impacted by the choices they made during the research or prototyping stage if their work was used.

Within the BME department of WPI, there are a variety of potential MQP subjects. During a qualitative examination of MQPs offered in previous years, as compiled through the WPI Gordon Library, different categories of project offerings were identified. These categorizations were made with consideration for what types of projects involve unique ethical considerations, such as direct integration of deliverables with human users, use of human cell lines, and management of the patient or subject data. Four categories of MQPs were identified: Treatments/Implants, Medical Devices, In vitro/In silico Models, and Measurement Devices.

Treatments/Implants projects include areas of research that will be implanted or administered as a treatment for a condition. Some examples of Treatment/Implants projects are a hearing aid, drug delivery projects, or a project involving cell scaffolds. The Medical Devices category includes areas of research that develop devices that can be used to treat patients, in a healthcare setting or as a part of daily life. Some projects include an assistive surgical robot, a respirator, or a diagnostic device. The In vitro/In silico Models category includes areas of research that create physical or virtual models for understanding, analyzing, or predicting, such as computational models, tunable micro-environments, and drug testing. The Measurement Devices category includes areas of research that develop devices or applications to take measurements. Some examples of projects in the Measurement Devices category include imaging techniques, an oxygen monitor, or a glucose measurement device. A categorical breakdown of 2022-23 BME MQPs reveals that out of thirty-two MQPs offered, nine projects fall into the In vitro/In silico category, eight into the Medical Devices category, eight into the Treatments/Implants category, and seven into the Measurement Devices category.

Project Need

The importance of undergraduate students learning the basis of ethics is well documented, however, the WPI BME department has yet to find an effective way to incorporate such an important subject. A lot of work can be done to ensure BME students consider the ethical impact of every aspect of their project. Teaching WPI students to consider ethics, as well as healthcare disparities, when designing, performing, and integrating their projects at the collegiate level helps to make sure universities like WPI are teaching their students to be ethical engineers and scientists in their research and designs. Despite all BME students having to fulfill an ethics requirement, their knowledge of ethical implications is lacking, as evident in the students' lack of thorough ethics statements in their capstone projects. Not only will students reap the aforementioned benefits from learning about ethics, but they will become ethical scientists and engineers, and will have the ability to make ethical considerations that will benefit broader society.

Our group's goal was to create a reliable online ethics course to be implemented into the BME curriculum. Through examining past Healthcare Disparities IQP projects, we planned and incorporated a similar online educational course, but with the goal of increasing student awareness and capabilities when constructing their MQP ethics statements. Additionally, by utilizing past Healthcare Disparities IQP projects, our group created and incorporated online modules through Canvas. Our modules aim to help BME students navigate the complexities and develop a deeper understanding of ethics when they are completing their MQP. Their ethics knowledge was evaluated by scoring the quality of the ethics statements they created as part of the course. Often overlooked in engineering, ethics plays a critical role in creating an honest and trustworthy system for engineering

professionals. Our project will create a positive impact on society as it fosters an understanding of ethics and allows students to apply this newly formed knowledge.

Methods

Approach

The goal of helping WPI BME students write effective ethics sections in their MQP reports including accounting for all ethical considerations to effectively meet the ABET requirements was approached by creating a set of online learning modules in the Canvas LMS. Sequential modules were created to walk the students through the process of creating meaningful ethics statements and to include possible effects of the project on increasing or reducing healthcare disparities. The interactive guide was created to reflect ABET criteria and based on an understanding of applied ethics. Students were given a background on ethics and healthcare disparities before delving deeper into topics pertinent to their specific MQP projects, which allows students to consider targeted ethics questions regarding their own projects. The goal of the interactive guide was to help prepare students to make ethical decisions in the future by considering ethics and healthcare disparities in relation to their MQP project. Students were also encouraged to consider how to decrease healthcare disparities, specifically in the healthcare field since most BME careers and students' current MQP projects involve human health and healthcare.

Sourcing Expert Feedback

In order to accurately understand the key components of an ethics education and to aid in the development of a thorough scoring rubric, ethicist, Doctor Yunus Dogan Telliel, an Assistant Professor of Anthropology and Rhetoric, co-chair of the Neuro-ethics subcommittee, professor of robotics ethics at WPI, and subject matter expert on ethics, was recruited. First, an informational interview with Doctor Telliel was conducted, which resulted

in the discussion of three themes that are particularly relevant to ethics education. (1) Doctor Telliel described informed judgment, which he defined as “being able to anticipate ethical issues that may be actualized later in the process” (Y, Telliel, personal communication, December 10, 2022). Informed judgment must be applied to every aspect of a project in order to fully comprehend all ethical implications. (2) Another key piece of information Doctor Telliel outlined was a branch of ethics known as “anticipatory ethics,” which he defined as “the practice of using the design phase to reflect upon how a system or technology's affordances will impact their use and potential consequences" (Y, Telliel, personal communication, December 10, 2022). (3) Finally, Doctor Telliel differentiated applied ethics and “big picture” philosophical ethics, as applied ethics refers to the real-world practice of moral considerations, whereas philosophical ethics is a much broader system, concerning itself with what is good and bad.

Scoring Rubric

In order to assess the impact of the interactive guide, a rubric was developed to analyze previous years’ BME MQP ethics statements and compare them to the ethics statements that were created after using the online modules. The methods that form the basis of this rubric were established based on the discussion with Doctor Telliel, as described in the previous section.

A scoring rubric was developed to reflect the three themes Doctor Telliel proposed. The rubric was used for prior year comparison and then further used to assess the ethics statements created after students completed the online modules (Table 1). The rubric was intended to be used as a tool to assess if students sufficiently hit all the characteristics of an ethical argument

that through discussion with Doctor Telliel were deemed as critical in order to have a complete and adequate ethics statement. The rubric was designed to assess students' satisfactory considerations of global, economic, environmental, and societal contexts, according to ABET requirements. Groups must also consider healthcare disparities in relation to their MQP project. Finally, groups should also explore the negative aspects of their project and compare their ethical decisions to other potential decisions they could have made, in the manner of a cost/benefit analysis. In summary, the main components that an ethics statement should consider are environmental ethical factors, societal ethical factors, global ethical factors, economic ethical factors, health disparities, and cost/benefit analysis. A simple point scale was assigned to these terms:

- 0 - "not present" was awarded when the group did not discuss the ethical consideration.
- 1 - "shallow" was awarded when the group identified possible ethical issues.
- 2 - "deeply mentioned" was awarded when the group had analyzed and unpacked the ethical issues and seen what issues could arise in the future of their research/product.
- 3 - "thorough analysis" was awarded when the group had a plan to avoid ethical issues that could arise in the future.

Table 1. *The first draft of the rubric.*

	Not Present	**Shallow**	**Deeply Mentioned**	**Thorough Analysis**
Environmental	/3	/3	/3	/3
Societal	/3	/3	/3	/3
Global	/3	/3	/3	/3
Economic	/3	/3	/3	/3
Healthcare Disparities	/3	/3	/3	/3
Cost/Benefit Analysis	/3	/3	/3	/3

Despite the simplicity of the design and numerical values assigned, this rubric was flawed in the organization of the "healthcare disparities" and "cost/benefit analysis" categories, which impacted the value of the points in the rubric. The rubric was updated so that the "cost/benefit analysis" category moved from a column to the top row, which meant it was assigned more weight, as a cost/benefit analysis should now be done for all of the four ABET categories (environmental, societal, global, and economic). As seen in Table 2, on the left of the rubric there is a column with the four ABET ethical factors to consider; environmental, societal, global, and economic. Along the top of the rubric are five criteria that should be discussed within each of the four ABET ethical factors, including, *Identified, Anticipatory, Mitigation, Cost/Benefit Analysis,* and *Healthcare Disparities*. For each ABET factor (environmental, societal, global, and economic), students earned one point for fulfilling each of the following criteria:

- *"Identified"* - must indicate an understanding of ethics in the scope of their project.
- *"Anticipatory"* - must establish a deeper level of understanding by demonstrating how the project will impact potential consequences.

- *"Mitigation"* - must have a complete understanding of ethics in the lens of the project.
- *"Cost/benefit analysis"* - must compare the costs to the benefits of their project.
- *"Healthcare disparities"*- must consider the preventable differences in the burden of disease, injury, and violence to achieve health for the socially disadvantaged.

Students received 1 point if they did fulfill the specific category requirement or 0 points if they did not. Based on this new rubric, the total possible score was 20 points. Compared to the previous rubric version, the decision to limit scores to either 0 or 1 in the new rubric resulted in a more straightforward and unambiguous scoring process. The final rubric developed can be seen in Table 2.

Table 2. *The final rubric that was created.*

	Identified	**Anticipatory**	**Mitigation**	**Cost/Benefit Analysis**	**Healthcare Disparities**	Total
Environmental	/1	/1	/1	/1	/1	/5
Societal	/1	/1	/1	/1	/1	/5
Global	/1	/1	/1	/1	/1	/5
Economic	/1	/1	/1	/1	/1	/5
Total	/4	/4	/4	/4	/4	**/20**

Prior Year Comparison

The scoring of previous years' BME MQP ethics statements was used as a baseline for student knowledge, while the scoring of the BME MQP ethics statements after interacting with our interactive guide was used to determine the effectiveness of the educational modules we created. For the prior year comparison, 33 MQPs that were written by students in the BME department during the 2021-2022 school year were evaluated. Reports were gathered

from the Digital WPI Project Library. Individual Projects were identified from a list of all 2021-22 BME MQPs obtained from the BME department's administrative assistant. To analyze each report, the portion that covered the ethical impacts of the project, often titled "Broader impacts" was reviewed. For this paper, we will refer to these as the reports' "ethics section". Formatting varied from project to project, so for a number of reports there was difficulty identifying the location of the ethics section. For these groups, we requested the completed "Advisor's Assessment of ABET MQP Outcomes AY2021-22" documentation for the project, where each team is required to identify the page of their project that meets the ABET requirement of recognizing the societal, economic, environmental, and global impacts.

To grade each report, two team members independently scored each ethics statement. After independent grading, the two team members met to discuss any discrepancies to reach a consensus on what points were given and to produce a final grade, which was then tabulated. The collaborative method of final grading was implemented so as to avoid giving elements a 0.5-point value, as the rubric grades each element on completion, not quality. For each project, the project name, project category, the completed rubric from each grader as well as the completed final rubric were recorded. Rather than just the total score for each project, the entirety of the rubric was recorded to allow for comparisons of individual rubric elements across the distribution of reports.

Prior to analyzing the entire list of 2021-22 reports, one report from each project category was graded independently by the same two team members. During the review of the four samples, the rubric was iterated to have more subjective grading criteria. The inter-rater reliability was evaluated by comparing individual grading discrepancies for the four samples which were graded pre-subjective grading criteria change and the remainder of the 33 reports

graded post-subjective grading criteria change. The inter-rater reliability was calculated by comparing the average discrepancy between the total grade given for each report by each grader as given by the equation:

$$\frac{\sum\left|report\ grade_{\ grader\ 1} - report\ grade_{\ grader\ 2}\right|}{total\ \#\ of\ reports}$$

For an outside opinion, the grading rubric was also provided to the pilot groups. Pilot MQP groups who were asked to complete the interactive guide were also asked to give feedback on the comprehension, readability, and usefulness of the rubric.

Overview of Online Learning

An online module was developed for the following reasons: (1) Online learning is common. Ever since the start of the COVID19 pandemic in 2020, online learning has become increasingly popular and it has completely changed the format of education. (2) Online modules are more sustainable. According to the Sustainable Business Toolkit, online teaching is sustainable in regards to the environment by helping to reduce the pollution and emissions from transportation, reducing energy consumption, and decreasing paper, plastic, and food waste (Nielsen, 2021). Online content is also more sustainable since it can be accessed anytime, anywhere, oftentimes without the need for an instructor. Of course, online content should be updated as new information is released. (3) Online courses can be easily implemented at WPI. The course was created on Canvas, which is the platform most courses at WPI use, so students are familiar with the interface. (4) Content online can be broken up easily. One article posted by the University of Northern Florida (UNF) from the Center for Instruction and Research Technology discusses how to engage students online and proposes

to make content relevant by grouping content into five to seven-minute chunks *(UNF Engaging Students In Canvas*, n.d.). In order to achieve small sections of information, the interactive guide includes modules with information and tools that took 5–10 minutes to work through. (5) Online learning can include various forms of instructional material. Thinkific posted a blog on how to make an online course more engaging and recommends differentiated instruction that acknowledges that each student absorbs information in different ways, whether it be text, video, audio, etc (Burton, 2022). The interactive guide created includes various forms of instructional material, including videos, infographics, and interactive quizzes.

Interactive Guide Development

As described above in the *Overview of Online Learning* section, the online format of the interactive guide was chosen due to its ability to be used at the student's ease. The interactive guide can be accessed asynchronously, so students with a demanding workload have flexibility when using this tool. In previous IQP projects, students created a one in-class lecture to educate students on healthcare disparities; the online format of the interactive guide allows for the content to be more sustainable and accessible, with the hopes of creating a long-lasting effect on the WPI curriculum.

The setup of the interactive guide was created to be as understandable and streamlined as possible. The modules include a variety of types of material, including text, video, "Check for Understanding" quizzes, discussions, and infographics, making the interactive guide inclusive for everyone's learning style. To keep a streamlined approach, each module functions as a prerequisite to the next, providing necessary information to continue through the interactive

guide. Following pilot group testing, the interactive guide was iterated based on feedback from the pilot groups and advisors.

Pre-Iteration Setup of the Interactive Guide

Module 1 - This module serves as an introduction to the interactive guide.

The first module functions as an overview of the goal and content of the course (see Figure 1). Once students have read through the Module 1 - "Welcome!," the next module introduces them to ethics on a broader scale.

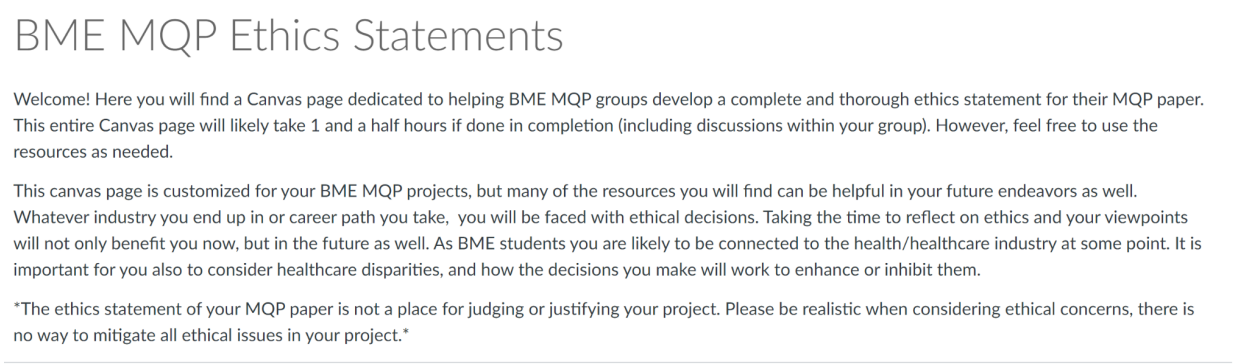


Figure 1. *Welcome Page in Module 1 of the interactive guide.*

Module 2 - This section provides an overview of ethics and includes "Check for Understanding" quizzes.

In Module 2 - "Ethics Overview," the students are given two videos each followed by a "Check for Understanding" quiz, which functions to assure that students have understood the necessary information from the videos provided. The first video on bioethics is created by FuseSchool, which is founded by Steve Dineen and creates easy to understand videos on a variety of topics and is trusted by thousands of teachers across the world (*FuseSchool - About Us*, n.d.). In this video, ethics is broken down very clearly and examples are given to understand its application to the real world, for example ensuring scientists' work is reviewed by ethical

review committees. This video relates well to the BME considerations as many of the examples given pertain to human beings and health.

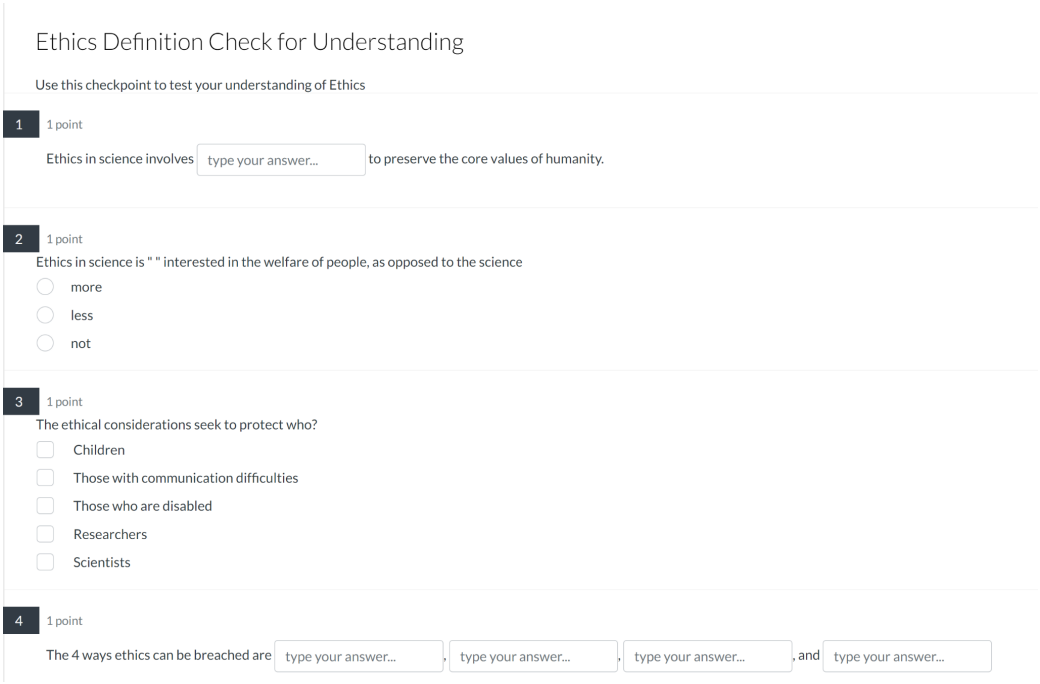


Figure 2. *Check for Understanding provided for Video 1 in Module 2.*

In the "Check for Understanding" (see Figure 2), we asked students to describe their fundamental takeaways from the video, ensuring they properly understood the material provided. The second video given in Module 2 discusses applied ethics, and was created by McCombs School of Business, from the University of Texas at Austin which has the Center for Leadership and Ethics, that teaches students about leadership principles and ethics through research and innovative content (*Center for Leadership and Ethics*, n.d.). This video delves deeper into applied ethics and teaches MQP students necessary ethical information, which is later tested in the "Check for Understanding" (see Figure 3).

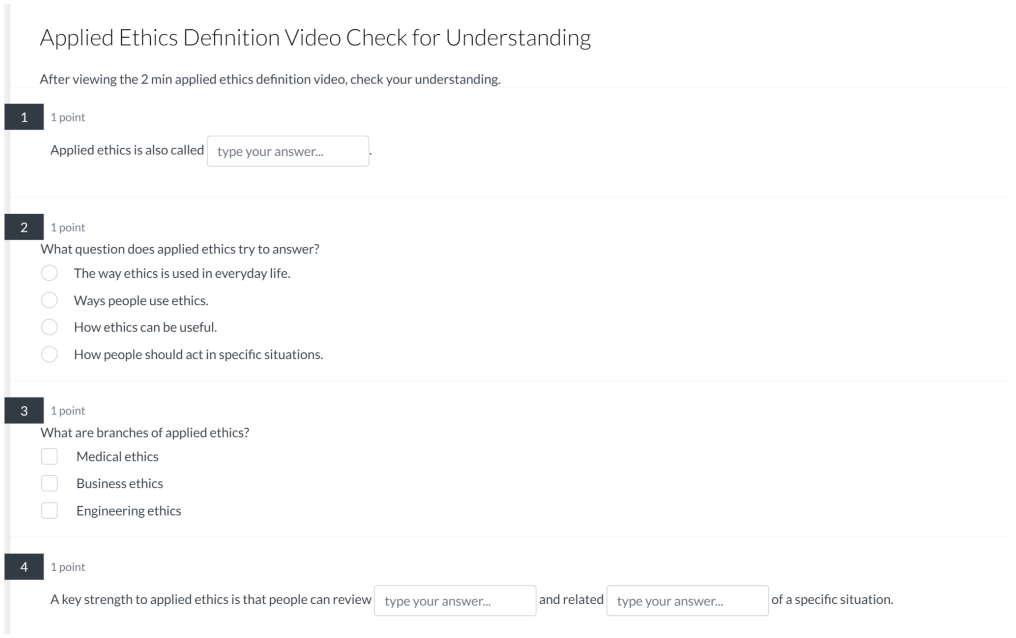


Figure 3. *Check for Understanding for Video 2 in Module 2.*

Module 3 - This section provides an introduction to ABET and how it relates to MQP projects.

The first two modules introduce ethics without much specificity, but Module 3 - "Four Ethical Considerations" aims to move the curriculum towards meeting the specific ABET requirements. In this module, the four ABET ethical considerations that students should consider (global, economic, societal, and environmental impacts) are introduced. Since students have a general understanding of ethics and applied ethics from Modules 1 and 2, students should be able to understand the principles and think about them in relation to their MQP projects. In this module, infographics were used to help highlight key points, such as the four ethical considerations and their relation to BME project group categories (see Figure 4).

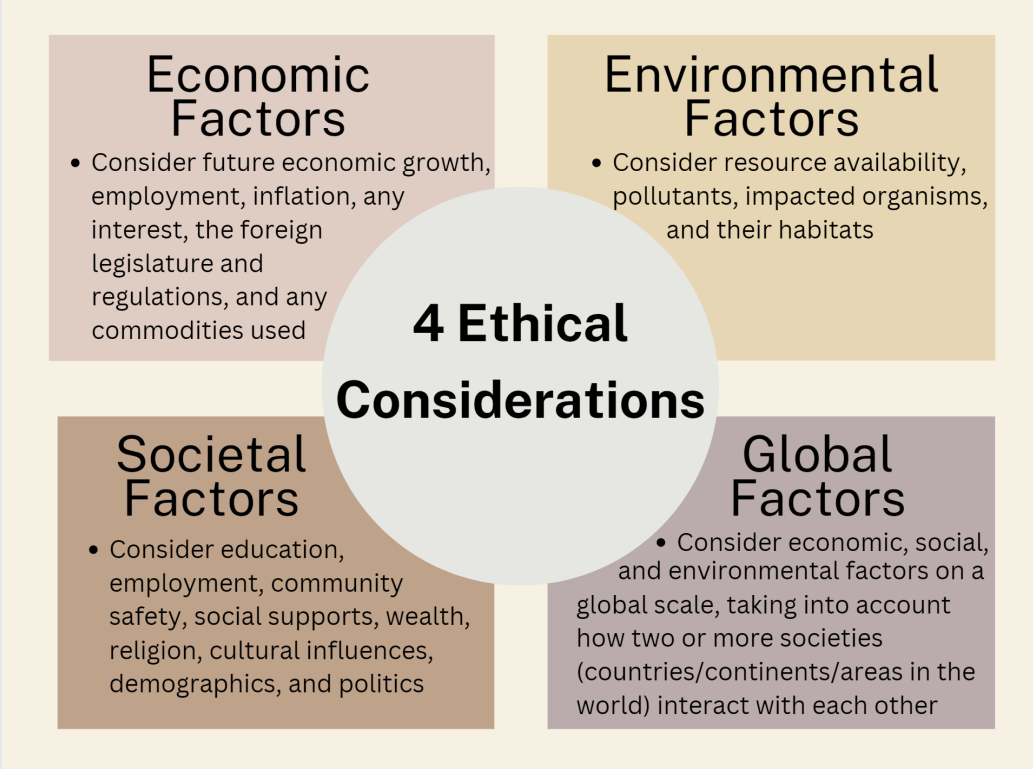


Figure 4. *The 4 ABET Ethical Considerations Infographic.*

In addition to the introduction of the four ABET ethical considerations, more information regarding healthcare disparities was provided in short paragraphs (see Appendix A). A video on healthcare disparities, created by Khan Academy, was also provided. In this video, Sal Khan goes over the many components of healthcare disparities highlighting how it impacts minorities and specific classes of people. Finally, the students were provided with an infographic to emphasize where healthcare disparities occur (see Figure 5).

Sources of Healthcare Disparities

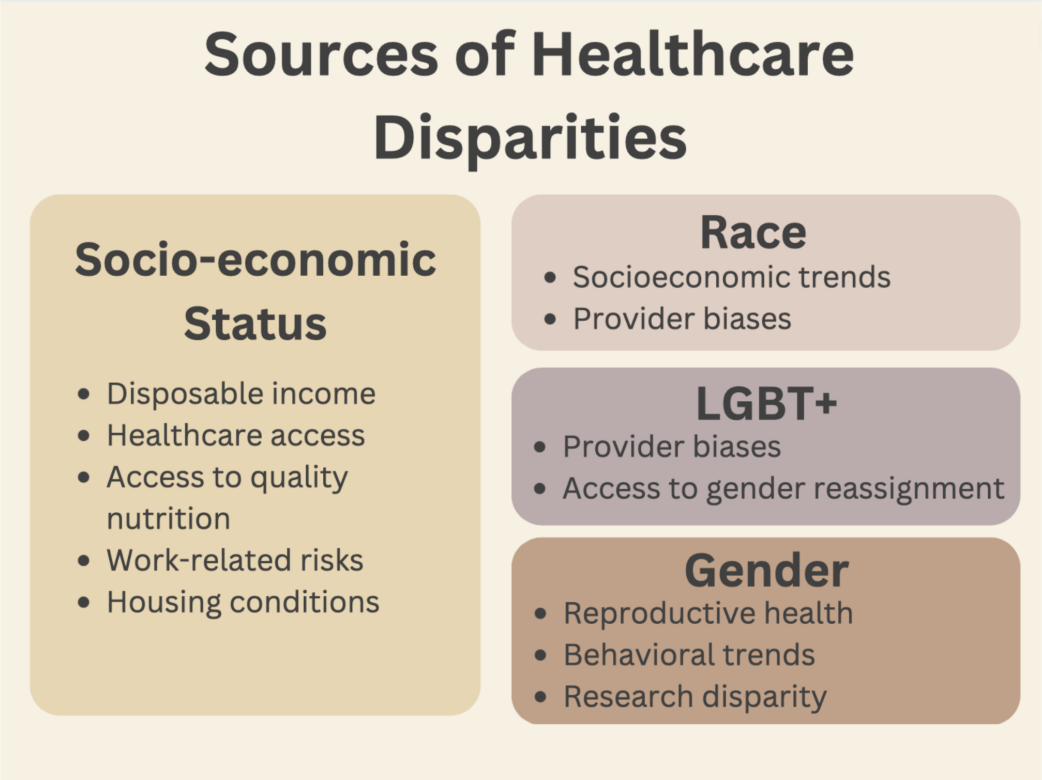


Figure 5. *Sources of Healthcare Disparities Infographic.*

Module 4 - This module introduces analyzing ethical decisions rather than justifying.

As mentioned in the *Prior Year Comparison* section, past MQPs were reviewed and there were many instances found where the MQP groups were justifying their project decisions without any real consideration, rather than stating where there could be issues and offering a potential solution. Initially in Module 4 - "Justifying Ethical Decisions," students are reminded that the ethics section of the paper is a place to analyze and consider, rather than defend their project and choices, as was done in past years MQP ethics statements (see Appendix B). To help the students with the justification process, the "Justifying Ethical Decisions" infographic was made to walk students through how they should be analyzing and remedying issues within their project (wee Figure 6).

Justifying Ethical Decisions

Figure 6. *Justifying Ethical Decisions Infographic.*

Module 5 - This module goes through how ethics statements are scored, viewed from the student's end.

Using the rubric created and described in the *Prior Year Comparison* section, in Module 5 - "Previous MQP Ethics Statements" the students are provided with instructions on the construction of meaningful MQP ethics statements along with an example from the past year (see Appendix C and D). In the provided example MQP ethics statement, each ethical consideration has been separated (global, economic, societal, and environmental), and each criterion from the rubric has been highlighted with corresponding colors. Within the sections, notes were added on where improvements could be made. It was emphasized that this ethics statement, while it has many good takeaways, is not an example to use as a template. From these two modules, the takeaway for the students is an understanding of the four ethical considerations and how they are applied within the ethics section.

Module 6 - This module introduces the different project categories and the types of projects that fall into them.

In Module 6 the four ethical considerations are introduced further. Module 6 is titled "Choose Your Adventure," because in this module ethical considerations are tailored to the different project types. It was found that BME MQPs fell into one or more of four categories: In Vitro/In Silico Models, Medical Devices for Treating Patients, Treatments/Implants, and Measurement Devices. To help students understand where their project fits in, an infographic was provided in which the categories were defined (see Figure 7). To help students place their project into a final category, one last infographic was included with example project types in the designated category (see Figure 8). As stated in the instructions for Module 6, students were encouraged to use the pages provided in Module 7, for more information on each project category.

Choose Your Adventure

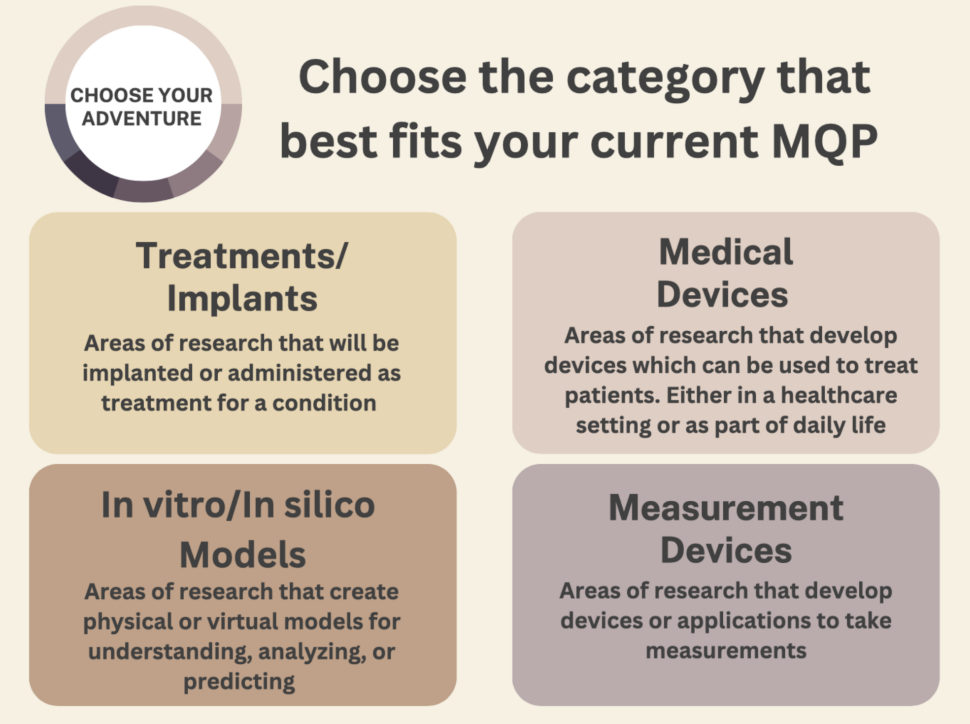


Figure 7. *The Choose Your Adventure Infographic further introduces students to the possible project types their MQP project could fit in.*

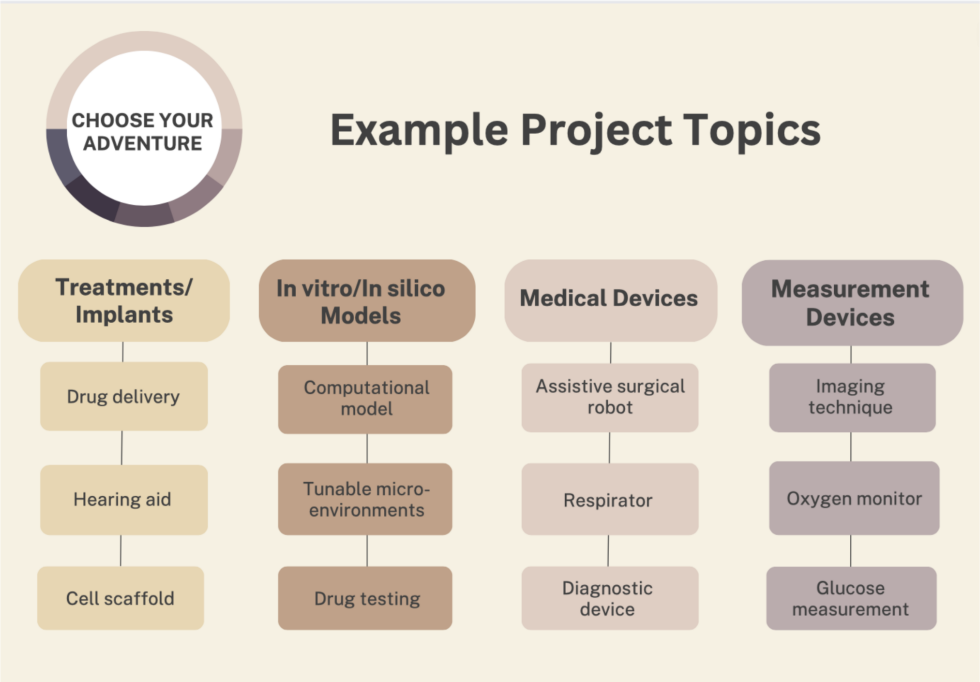


Figure 8. *The Example Project Topics Infographic helps students place their MQP project into a category.*

Module 7 - This section goes through specific ethical considerations for each project type, and how they can use these specificities to enhance their ethics statements.

In Module 7 students find the four infographics described earlier, with specific considerations based on their project category. There is one infographic for each project type (see Figures 9-12). By providing ethical considerations specific to the project type, students are given starting points for what should be included in their own statements.

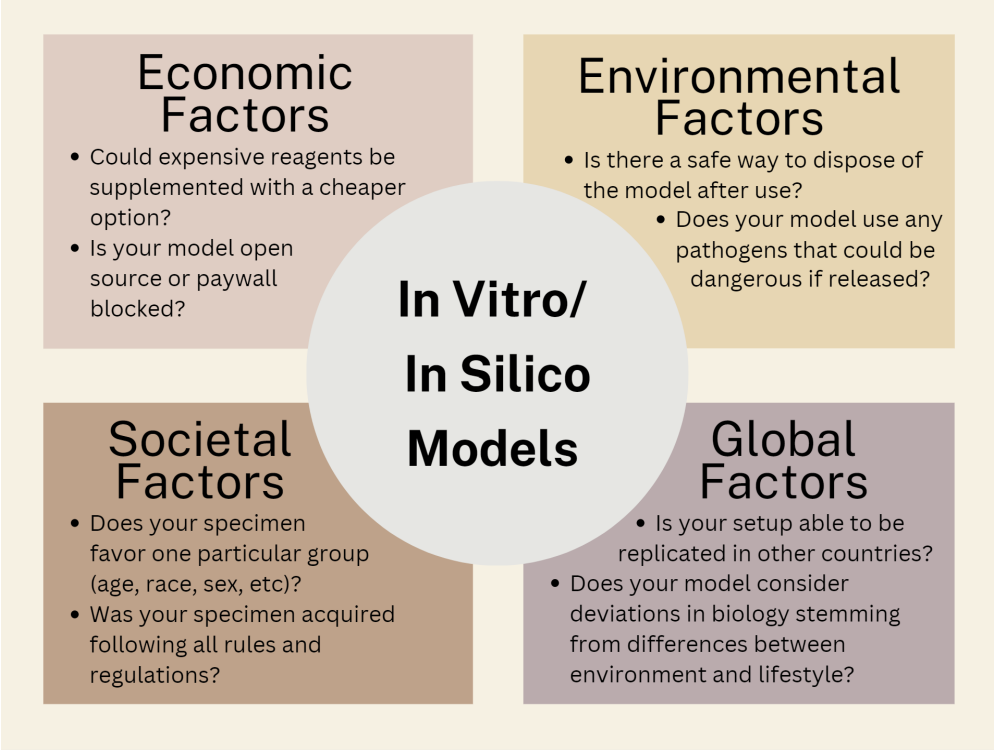


Figure 9. *In Vitro/In Silico Model Infographic.*

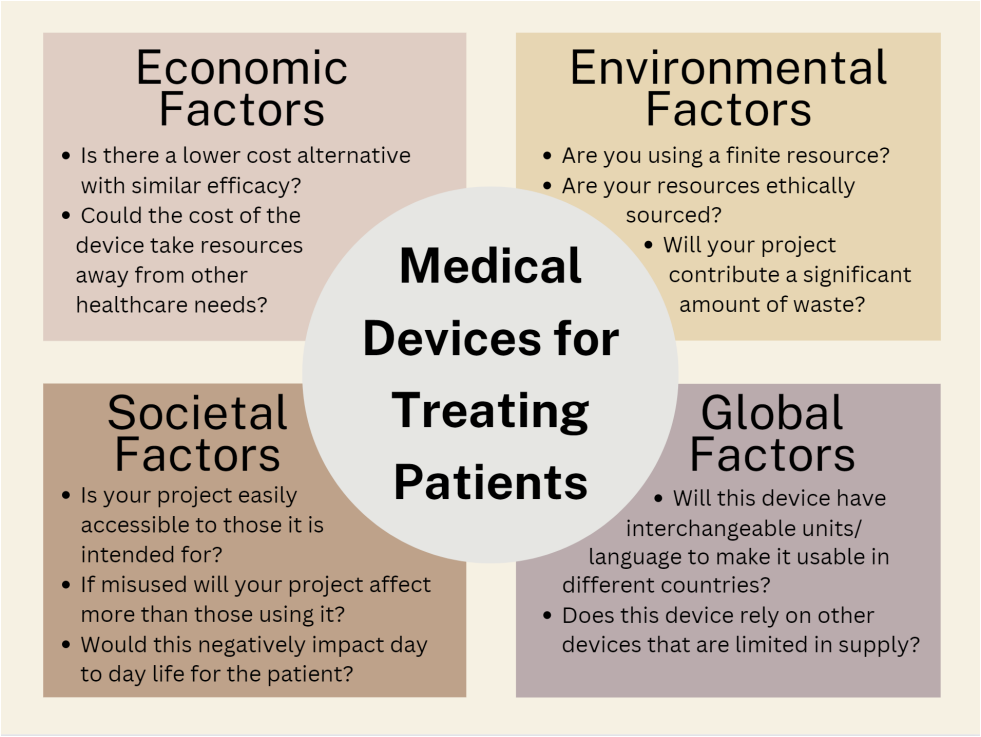


Figure 10. *Medical Devices for Treating Patients Infographic.*

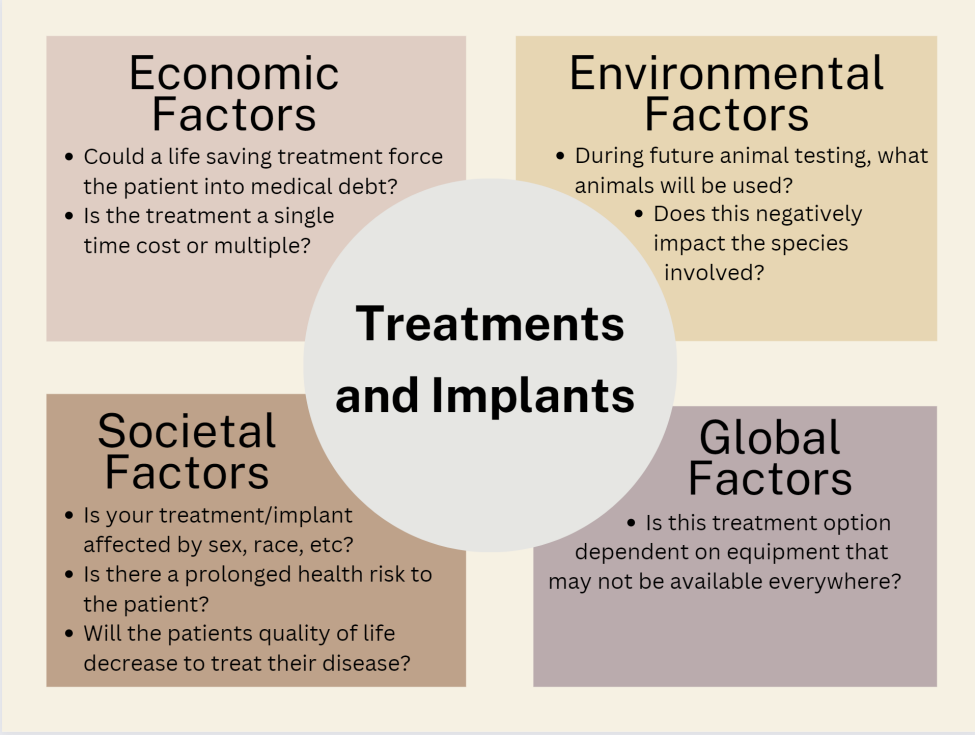


Figure 11. *Treatments and Implants Infographic.*

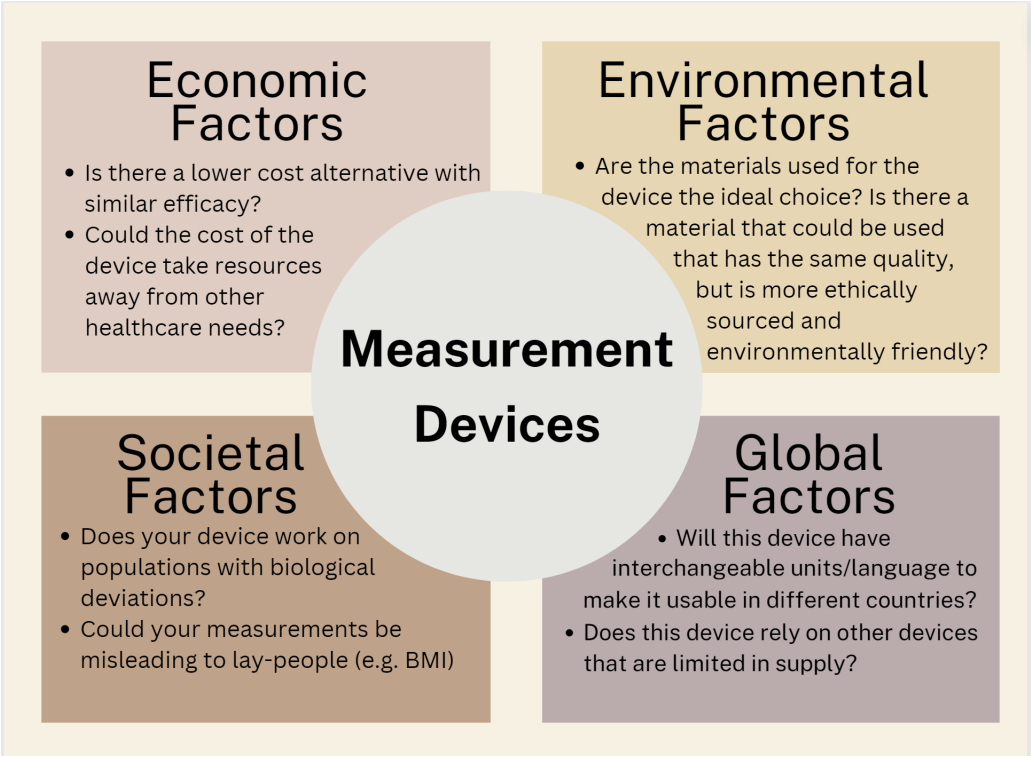


Figure 12. *Measurement Devices Infographic.*

While the main target of the interactive guide is the students writing the ethics statement of their MQP paper, it was important to include the advisors in the ethics discussion to gain more perspective on the ethics of the project. Many advisors have more in-depth knowledge on the subject matter and ethics in the BME field, so they can help facilitate a more meaningful discussion. After students have completed Modules 1-7, which provide them the necessary knowledge on ethics, healthcare disparities, and ethical considerations for their project, they were asked to have a conversation with their advisor, in Module 8.

Module 8 - This section explains the advisor discussion, which is led by the students and guided with non-group specific questions regarding ethics.

In the Module 8 instructions, an outline for the discussion is provided, advising students and advisors to look over the questions provided, and then have a roughly twenty-minute conversation as a group about the ethical implications of the project (see questions in Appendix E). In addition to the questions, advisors have their own module within the interactive guide where they can find information on the ABET requirements, and a link to the website (see Appendix F). With this discussion, students are able to cross-check their ideas regarding the project's ethics with their advisor, who has worked in the field and is able to use their experience to benefit their group. Leaving this discussion, the students are equipped to write their ethics statements.

Module 9 - This module provides an infographic that functions as a reminder of what students should be addressing in their ethics statements

Module 9 - "Writing your Ethics Statement," is the last tool given to the students to write their ethics statements. In this module, students are reminded to take what they have learned and put it into their final product, and to look back at any of the resources given to them. The final

infographic of the tutorial contains everything that should be included in an ethics statement (see Appendix G).

To conclude this tutorial, each group was asked to complete a feedback survey (see Appendix H). In this survey, students submit their ethics statement and rate the effectiveness of the learning materials. The ethics statements were then graded using our rubric and compared to previous MQPs to see if our module was effective in improving the statements. The feedback on the course itself was used to revise the interactive guide accordingly.

Iteration of the Interactive Guide

After the initial pilot testing concluded, feedback from the students in the feedback survey and direct feedback from the advisors was used to improve our interactive guide (see *Results* for more details). With this, Modules 1 through 5 stayed the same. Module 6 was changed to an introduction to choosing the right category for the project, followed by the "Choose Your Own Adventure" Infographic (see Figure 7). The last part of this module is the "Example Project Types" Infographic.

The final module is Module 7, merged with aspects of Modules 8 and 9 to make the interactive guide more concise. Previously, Module 8 was the "Advisor Discussion" module and gave students a list of general questions to guide a conversation with each group's advisor. These questions were non-specific to any project type. Feedback from the pilot group advisors was that these questions were too broad to get into the ethics of each specific project. It was decided to take these out of the module, substituting them for the project-specific questions. With these questions, each group should be able to have a more impactful conversation with their advisor. In addition to specific questions, a checklist was provided to help guide their discussion so they hit

the key points of what would be in their ethics statements. Module 9 proved to be unnecessary on its own and was incorporated into the ethics statement checklist for the updated Module 7.

Analysis

Analysis: Prior Year Comparison

For the prior year comparison, our group analyzed 33 MQP ethics statements using the rubric we created. Two group members scored each ethics statement from the past academic year using the rubric created, checking to see if it hit all 4 ethical concerns, as well as accounting for the anticipation of ethical concerns, how they were mitigated, cost/benefit analysis, and whether any healthcare disparities were addressed. All of these ethics statements were assigned a score from 0-20.

Analysis: Pilot Testing

For the Pilot Testing, 4 current MQP groups and their advisors were recruited to participate in the interactive guide. Students in the MQP groups submitted both their ethics statements and feedback through the feedback survey at the end of the module. The ethics statements were then scored by our team. For the statistical analysis, the R programming language was used to find the correlation and *p-value*. The values obtained from R were exported to Excel to further validate the data. From the student and advisor feedback, changes were made to the interactive guide. These changes helped our learning system become more streamlined and a better tool for the students.

Analysis: Final Testing

After modifications were made to the online ethics module, it was sent out to all of the 2023-2024 BME MQP groups as an option to aid in writing the ethics section of their paper.

After the interactive guide was sent out to the 2022-2023 BME MQP groups, there were 23 teams who chose to participate. These groups submitted their ethics statements through the feedback survey given at the end of the module. Our team then used the rubric to score the statements. An ANOVA was then performed comparing the 2021-22 ethics statement scores to the 2022-23 ethics statement scores for both the total scores and each category of scores (ABET categories and ethical consideration categories), to analyze the effectiveness of the online ethics module in improving the ethics statements. For each category of scores *Cohen's d* between the 2021-22 and 2022-23 years was also calculated for the effect size.

Results

Prior Year Comparison Results

Ethics statements obtained from the 2021-22 MQP reports consistently scored low when scored in conjunction with the evaluation rubric (see Figure 13). The average score for the prior year ethics statements was a 3.6 out of 20 possible points, with a standard deviation of 3.3. Of the 33 ethics statements that were evaluated, ~75% scored at or below a 5, and ~95% scored below at or below a 10. No reports from the 2021-22 group scored above an 11.

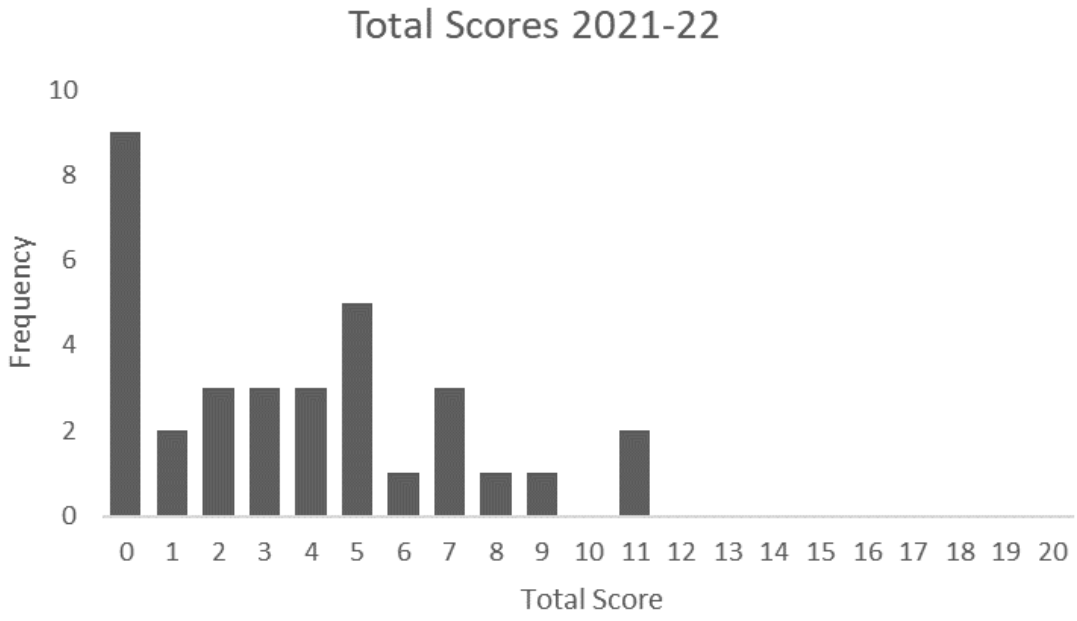


Figure 13. *Total scores for 2021-22 BME MQP ethics statements.*

The breakdown of the average scores and standard deviations by ABET category and ethical consideration category can be seen in Figure 14.

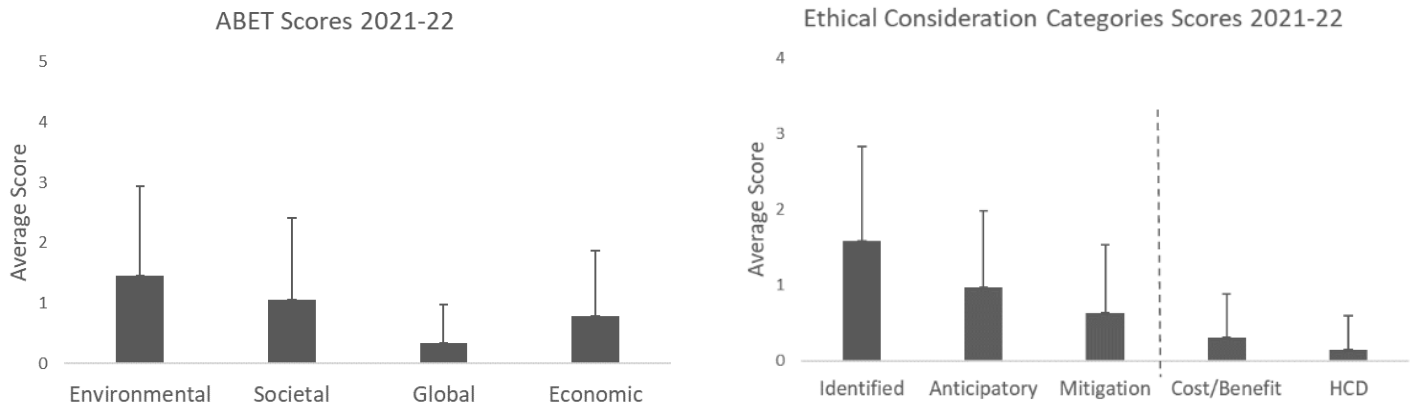


Figure 14. *Average category scores for 2021-22 BME MQP ethics statements. Students could earn 1 point for each category. Left - ABET scores or the level of ethical considerations that ABET recommends, out of a total possible 5 points. Right - ethical consideration category scores with increasing complexity of ethical consideration, out of a total possible 4 points. Healthcare disparities = HCD. Dotted line indicates division between fundamental ethical considerations and higher level comparisons.*

When broken down into the different ABET categories, all four scoring distributions were heavily distributed toward 0, which can be seen in Figure 15. Notably, no reports scored a full 5 points in any ABET category. Additionally, it was observed that the *environmental* category exhibited the highest proportion of 3+ point scores, whereas the *global* category had the highest proportion of zero point scores.

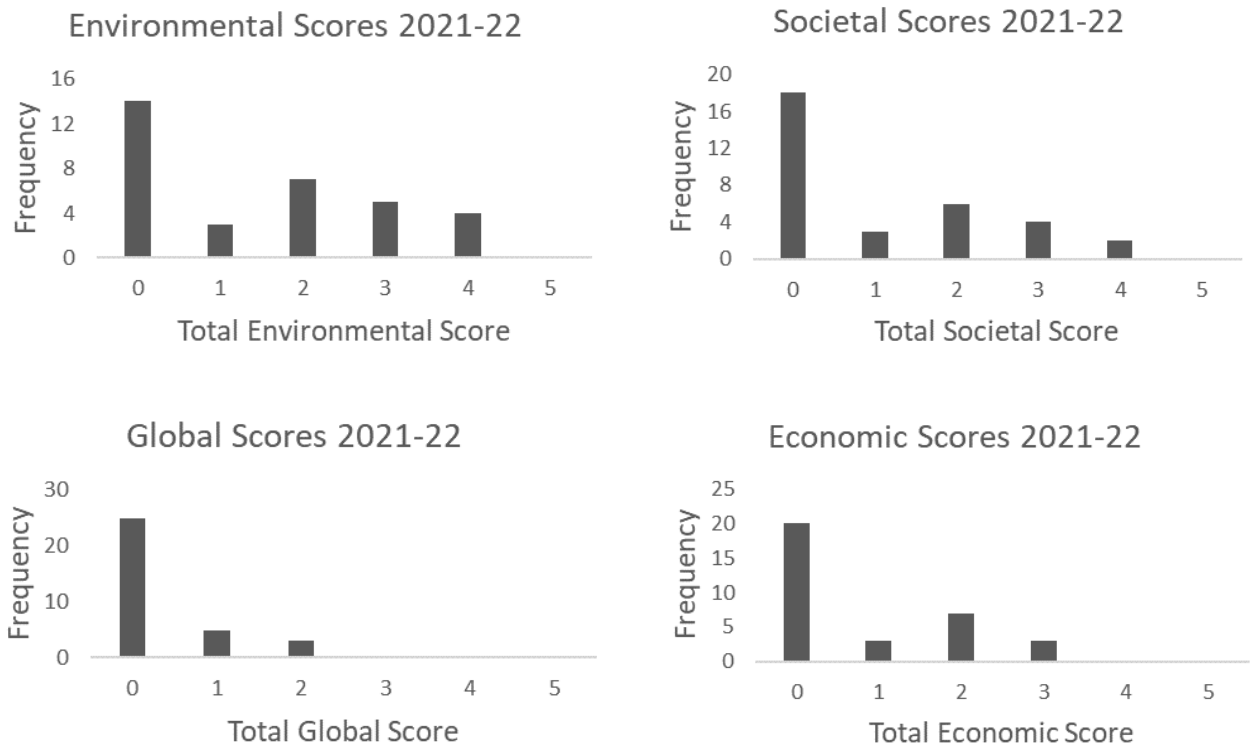


Figure 15. *Distribution of scores in each ABET category for 2021-22 BME MQP ethics statements.*

When broken down into ethical consideration categories, point distributions had a wider variation in shape depending on the criterion, which can be seen in Figure 16. While the distributions for *Mitigation*, *Cost/Benefit Analysis*, and *Healthcare Disparities* exhibit a heavily right-skewed shape similar to those broken down by ABET category, the *Identified* criterion exhibited a fairly even distribution of scores across the 0 to 3 point range. The *Identified* criterion is also the only scoring breakdown that included a full point score, including the ABET category breakdowns. *Anticipatory, Mitigation, Cost/Benefit Analysis, and Healthcare Disparities* criteria were found to have 36%, 27%, 18%, and 9% of reports earning 1/1 point scores respectively. *Cost/Benefit Analysis* and *Healthcare Disparities*, which can be listed as higher level criteria

were shown to have the highest proportions of 0 point scores and all 33 reports failed to score above 2 points in each criterion.

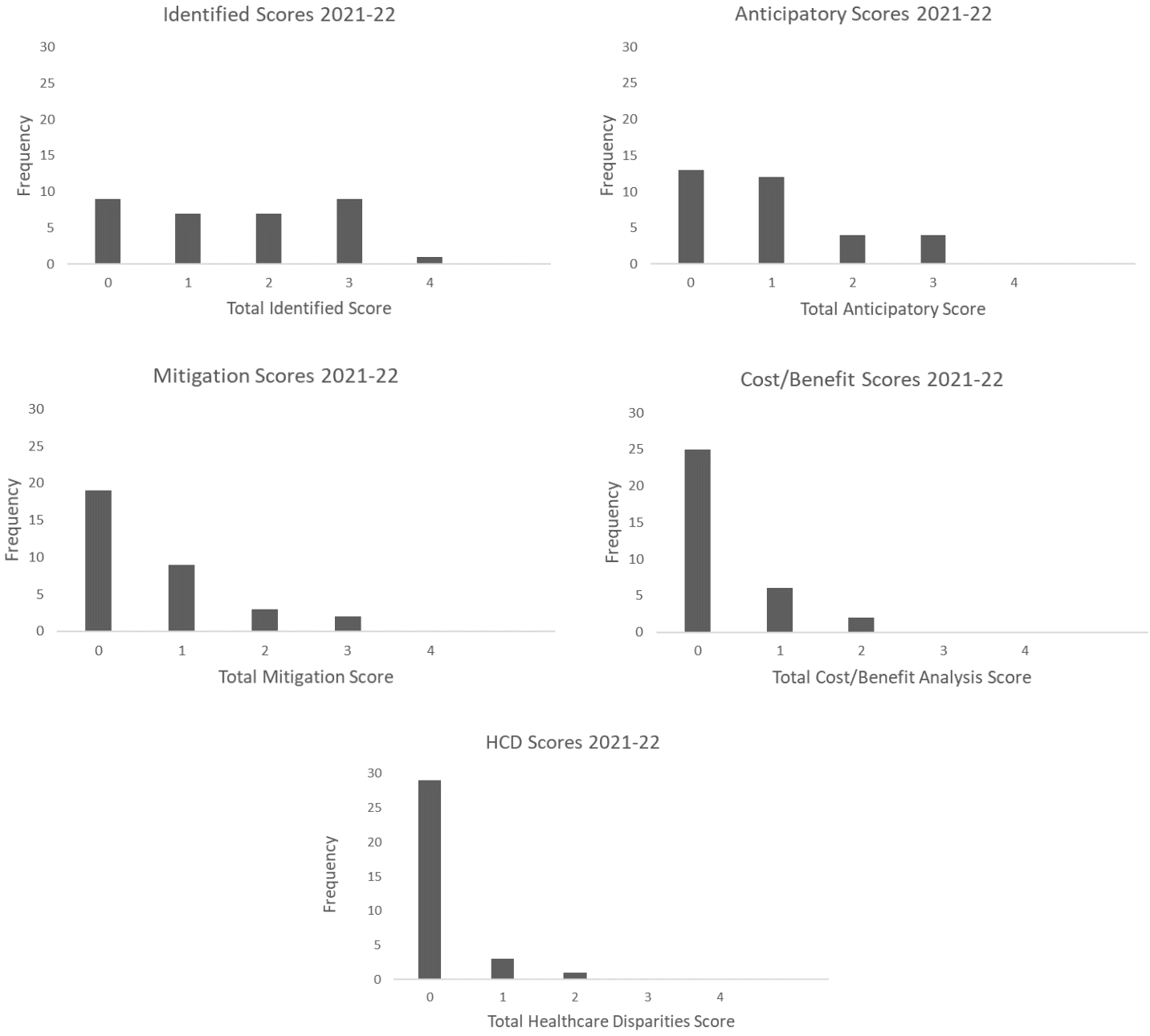


Figure 16. *Distribution of scores in each ethical consideration category for 2021-22 BME MQP ethics statements. Top left - Identified. Top right - Anticipatory. Middle left - Mitigation. Middle right - Cost/Benefit Analysis. Bottom - Healthcare Disparities.*

Pilot Groups Results

From the 4 pilot groups, 3 groups submitted an ethics statement, and the average rubric score was 10.0 points out of 20, with a reported standard deviation of 4 points. Despite the scores still appearing on the lower end of the grading scale, the pilot groups saw increases in their ethics statements scores. Last year's average ethics statements score was 3.6 points, whereas the average ethics statement score of the pilot groups was 10.0 points, which is an increase of 6.4 points. Additionally, the highest scoring statement from the pilot was 3 points higher than the highest scoring statement from the prior year comparison, at 14 and 11 respectively. The finalized rubric scores for each pilot group submission are included in the figures below, anonymized for the groups' privacy.

Table 3. *Finalized rubric score of pilot group "A."*

	Identified	**Anticipatory**	**Mitigation**	**Cost/Benefit Analysis**	**Healthcare Disparities**	Total
Environmental	1	1	0	1	0	3/5
Societal	1	0	0	0	1	2/5
Global	1	0	1	0	1	3/5
Economic	1	0	0	1	0	2/5
Total	4/4	1/4	1/4	2/4	2/4	**10/20**

Table 4. *Finalized rubric score of pilot group "B."*

	Identified	**Anticipatory**	**Mitigation**	**Cost/Benefit Analysis**	**Healthcare Disparities**	Total
Environmental	1	1	1	0	0	3/5
Societal	1	1	1	0	1	4/5
Global	1	1	1	0	1	4/5
Economic	1	1	1	0	0	3/5
Total	4/4	4/4	4/4	0/4	2/4	**14/20**

Table 5. *Finalized rubric score of pilot group "C."*

	Identified	**Anticipatory**	**Mitigation**	**Cost/Benefit Analysis**	**Healthcare Disparities**	Total
Environmental	1	0	1	0	0	2/5
Societal	1	0	0	0	0	1/5
Global	0	0	0	0	0	0/5
Economic	1	1	0	0	1	3/5
Total	3/4	1/4	1/4	0/4	1/4	**6/20**

While all 3 groups performed above the average of the prior year comparison, each group exhibited different distributions of scoring within the rubric. This was important for revising the online ethics statements, as groups continued to struggle on developing a cost/benefit analysis. Group "C" had points scattered throughout the rubric, but failed to meet even a single point in the global category (Table 5). Group "A" consistently met the *Identified* criteria for all 4 categories, but any additional points were distributed across the multiple categories and grading criteria (Table 3). Group "B" scored the highest and was by far the most consistent, with points scored for all 4 categories in not just *Identified* but also the *Anticipatory* and *Mitigation* criteria

as well (Table 4). However, Group “A” was able to score more points in the last 2 higher-level criteria of cost/benefit analysis and healthcare disparities than Group “B”.

Pilot Group Feedback

The online learning modules were developed in the Canvas LMS. In order to receive feedback on the interactive guide, a Qualtrics survey was developed, and a link to the survey was included at the end of the interactive guide. The survey included open-ended, multiple-choice, and Likert-scale questions (Appendix H). Open-ended questions enabled respondents to provide detailed feedback in their own words, while multiple-choice questions provided a structured and standardized approach for data collection. The Likert-scale questions allowed participants to indicate their feelings and attitudes on a standardized scale, which provided a consistent measure of their opinions. By incorporating three different question types, the survey was able to capture a range of data and perspectives from the participants. In the survey, students also submitted the ethics statement that their group created using the interactive guide.

In the first pilot group, four MQP groups were recruited from different project categories, which are described in the *Online Canvas Page Development* section. The four pilot groups, their project group advisor, project name, and category can be seen in Table 6.

Table 6. *The four pilot groups' advisor, project, and corresponding category.*

Advisor	**Project**	**Category**
Professor Billiar	Fluid flow stimulation of engineered heart valve tissue	In Vitro/In Silico models
Professor Billiar	Device to aid mechanical ventilation of obese patients	Medical devices for treating patients
Professor Albrecht	Accurate, unintrusive, continuous blood pressure monitor	Measurement devices
Professor Ambady	Wound healing bandage	Treatments/Implants

The survey took on average five minutes to complete and a total of *n*=5 students took the survey. Two survey participants were a part of Professor Billiar's "Device to aid mechanical ventilation in obese patients" team, two survey participants were a part of Professor Billiar's "Fluid flow stimulation of engineers heart valve tissue" team, and one survey participant was a part of Professor Ambady's "Wound healing bandage" team. The results from this survey do not account for the fact that some students may not have fully participated in the interactive guide as they may have gone through the modules together.

At the beginning of this survey, students were asked to rate their knowledge regarding ethics and healthcare disparities before going through the interactive guide. From 1 being "I did not know what ethics nor healthcare disparities were" to 5 being "I knew an extensive amount about ethics and healthcare disparities," on average students rated their knowledge between a 2 and a 4 on the 5-point scale with an average of 2.8. Students were then asked to rate their knowledge regarding ethics and healthcare disparities after going through the interactive guide. Based on the same Likert-scale, all the students (*n*=5) rated their knowledge a 4 after completing the course, showing a 1.2-point increase. Students were also asked to rate how different their ethics statement was after using the interactive guide versus if they had not used it. From 1 being

"extremely worsened" to 5 being "extremely improved" with 3 being "neither improved nor worsened." One student selected "neither improved nor worsened" and four students selected "somewhat improved," resulting in an average of 3.8.

In the survey, students also rated their overall experience with the interactive guide. From 1 being "overall, the course was bad" to 5 being "overall the course was great," on average students rated the interactive guide a 4; ratings [2, 4, 4, 5, 5]. Students were also asked to rate their feelings based on the statement, "the Canvas course was helpful in the development of our MQP ethics statement." From 1 being "strongly disagree" to 5 being "strongly agree," on average students rated this statement 4.8; ratings [4, 5, 5, 5, 5]. In addition, students were asked to rate their feelings on the statement, "the Canvas course was clear and well-defined." Using the same scale, students rated this statement another 4.8; ratings [4, 5, 5, 5, 5]. Finally, students were asked to indicate how long it took to go through the interactive guide, including the advisor discussion, as well as how long they spent writing their ethics statements. On average it took students 60 minutes to go through the interactive guide (range: 20-90 minutes) and 60 minutes (range: 20-90 minutes) for students to then write their ethics statement.

The final question of the survey is an open-ended question asking students for any other feedback or suggestions. After receiving feedback from two students, the student feedback was reviewed and modifications were determined to implement in the interactive guide. One student suggested for the interactive guide to be a part of the syllabi for MQP projects, and for the modules to be given to students earlier in the school year. No revisions were implemented since the intention is to integrate the interactive guide into the WPI BME curriculum in the future and include it in the syllabi distributed at the beginning of the academic year, which was not feasible this year due to the timeline of our project. The other student suggested that the quizzes

following the videos were not challenging enough and should be more focused on critical thinking. However, no iterations were made based on this suggestion, as the videos and quizzes were meant to provide background information, and most of the critical thinking was expected to occur when students crafted their ethics statements. Although no iterations were made from the additional feedback of students, iterations were made based on advisor feedback (see next section). Overall, the results from the feedback survey prove the overall effectiveness of the course, as students improved their knowledge of ethics and healthcare disparities while also enhancing their ethics statements.

MQP Advisor Feedback

Following a pilot test of the interactive guide, advisor feedback was solicited and provided by Professor Albrecht and Professor Billiar. An example ethics statement provided with the scoring rubric in the ethics modules was deemed helpful, and the MQP advisors suggested incorporating additional examples of such statements from different project types. It was decided not to modify this element as the interactive guide already provides specific guidance on what various project types should include in their ethics statements. Including more examples could potentially create clutter and take too long for groups to complete, and one goal was to ensure the interactive guide gave students a complete and thorough ethics education in a short amount of time. Another aspect of the received feedback from the MQP advisors regarded the timing of the project, with the observation that C term may not be the most suitable period for students to concentrate on the paper, as many are still completing prototypes of their MQP projects instead of writing their papers. Unfortunately, due to the timeline of this project, C term was the only viable term to collect and analyze data for our project. In the advisor discussion module, students

were provided with a set of questions to guide the discussion. These questions can be seen in Figure 17.

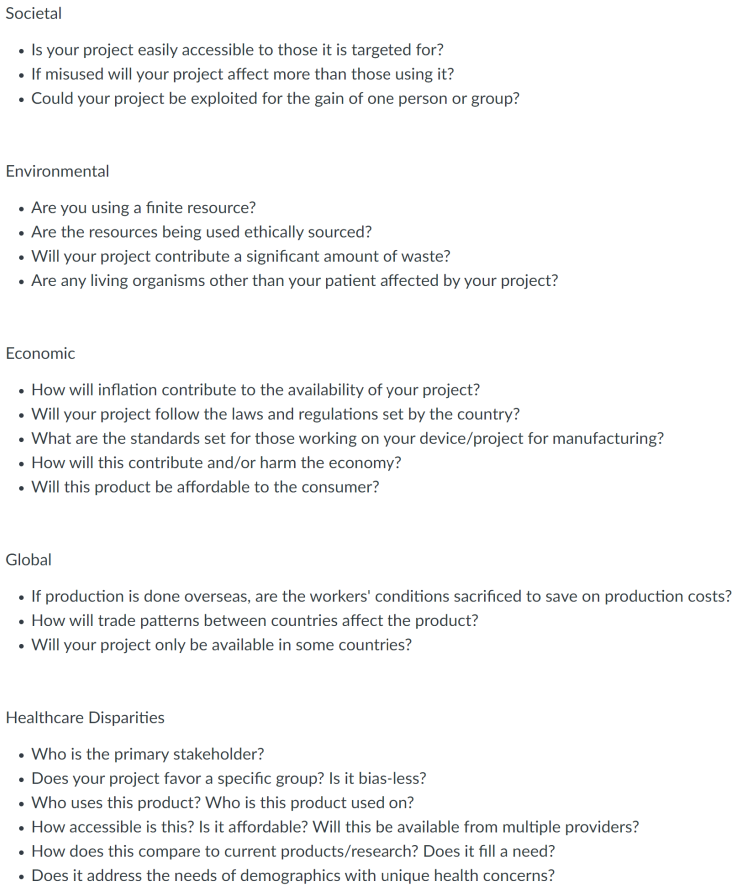


Figure 17. *Initial questions provided for Advisor Discussion*

Both professors expressed their dissatisfaction with the imprecise nature of the questions seen in Figure 22, as some items were not relevant to the MQP pilot groups. The MQP advisors also suggested that the questions were too prompting and did not let students think critically about their project. Furthermore, it was noted that the professors found it challenging to engage in discussions with the groups as the advisor had no prior involvement in the online modules. To remedy this, we placed project-specific questions in the revised module and asked that both advisors and students review them to facilitate a more productive discussion. The module now includes the initial questions as a checklist that the groups could utilize to ensure they cover all

the necessary topics during the conversation, as well as more project-specific questions, as seen in Figures 9-12. By having the advisors look over the questions before the discussion, the advisors could better comprehend the objective of the discussion. However, going forward, it would be best for the advisors to engage in the entire learning system to provide better support for their MQP teams.

Full Participation Results

After making the interactive guide available to all the 2022-23 BME MQP groups, a total of 23 ethics statements were submitted for scoring. Our rubric evaluation revealed an average score of 8.9 out of 20, with a standard deviation of 4.35, as seen in Figure 18. This is a +145% increase from the prior year comparison total score average. The distribution of scores for the full participation testing results can be see in the figure below.

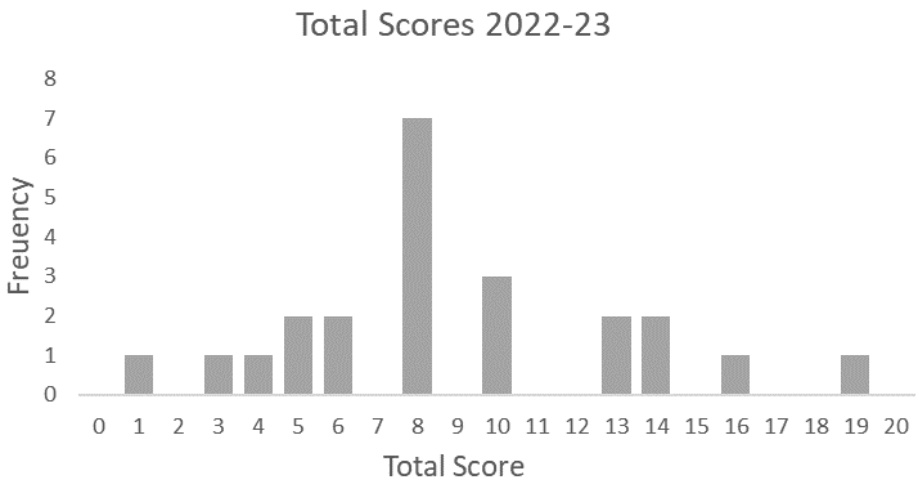


Figure 18. *Distribution of full participation ethics statement total scores.*

Analysis of scoring within each ABET category shows higher scores for all ABET categories, with the most improvement in the *economic* category. The average scores within each

category were 2.5, 2.5, 1.4, and 2.5 for *environmental*, *societal*, *global*, and *economic factors*, respectively (see Figure 19). While improvements were made, the data shows that of the four categories, students struggled to score points for the *global* category the most.

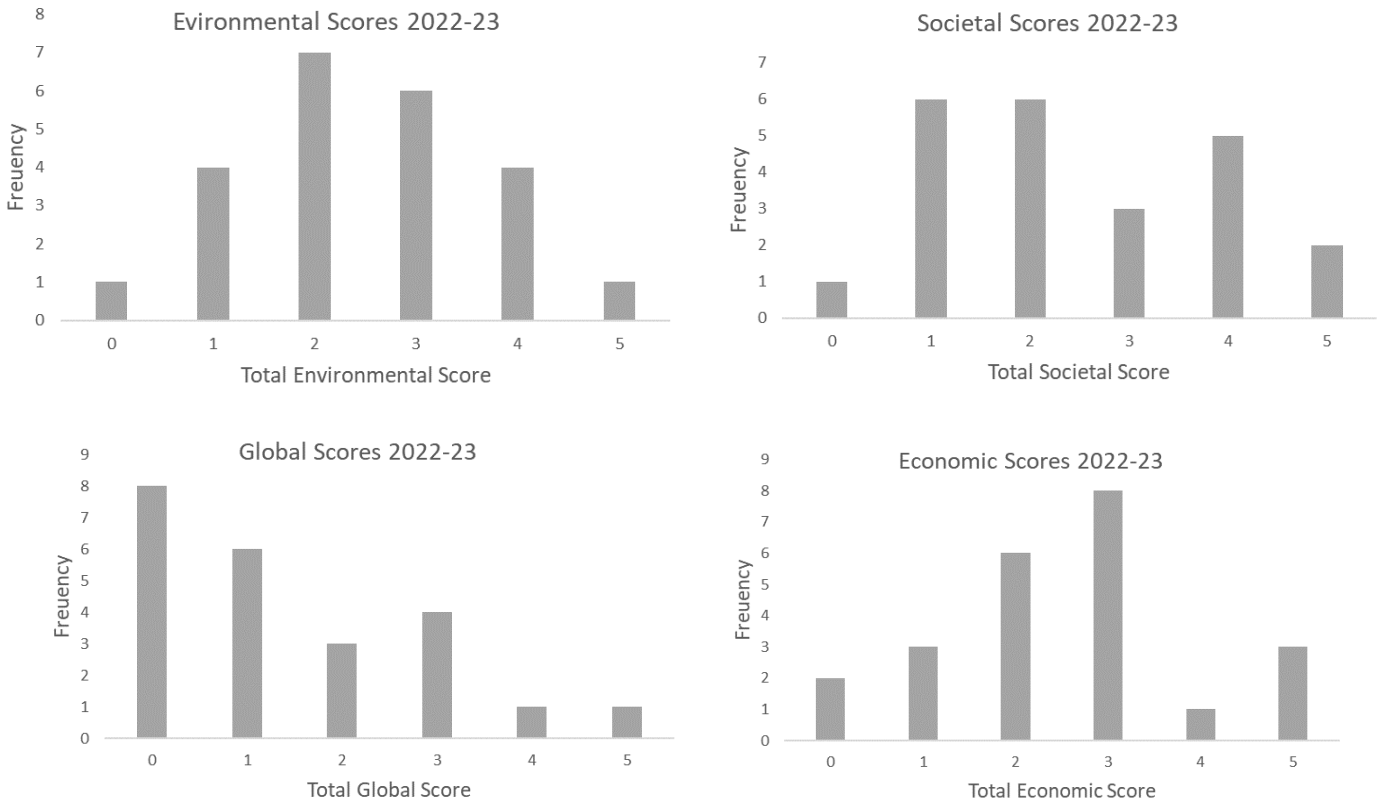


Figure 19. *Distributions of scoring for individual ABET categories for 2022-23 BME MQP ethics statements: Top left - Environmental factors scoring distribution. Top right - Societal factors scoring distribution. Bottom left - Global factors scoring distribution. Bottom right - Economic factors scoring distribution.*

As shown in Figure 19 above, the scoring distributions for all the ABET categories had a higher mean meaning a larger portion of projects were scoring at higher level, compared to the 2021-22 BME MQP ethics statements. The averages based on ABET criteria can be seen in Figure 20.

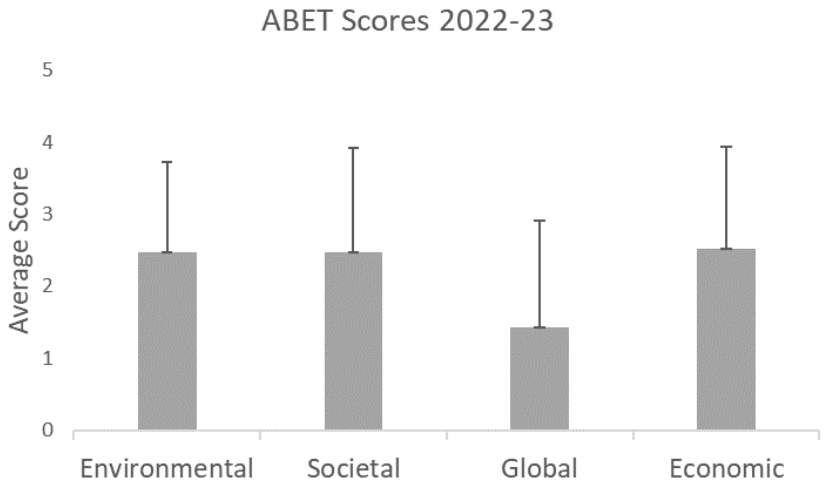


Figure 20. *Average scores of individual ABET categories for 2022-23 BME MQP ethics statements*

Scores were also categorized by the ethical consideration categories as seen in the top row of the rubric. Scoring distributions for each grading criterion revealed students achieved higher scores for the *Identified* criterion (see Figure 21). Average *Identified* score improved from a 1.6 in the prior year comparison to a 3.5 out of 4 in the full participation testing. The categories of *Anticipatory* and *Mitigation* also saw improvements in scoring, but unlike the ABET categories, the score frequencies are fairly even between scores. The average scores based on ethical consideration categories can be seen in Figure 22.

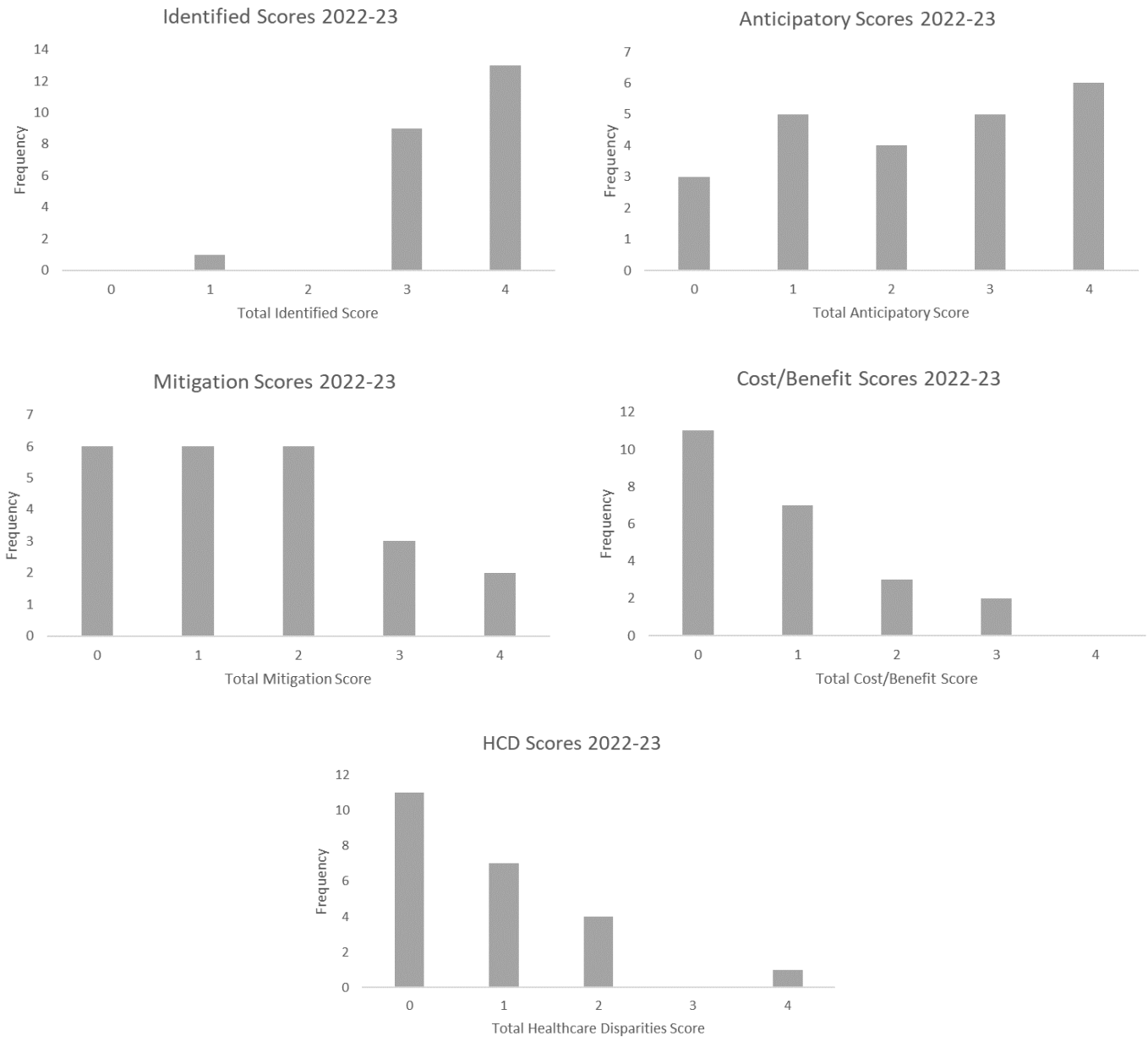


Figure 21. *Distributions of scoring by ethical consideration categories for 2022-23 BME MQP ethics statements. Top left - Identified scoring distribution. Top right - Anticipatory scoring distribution. Middle left - Mitigation scoring distribution. Middle right - Cost/Benefit Analysis scoring distribution. Bottom - Healthcare Disparities scoring distribution.*

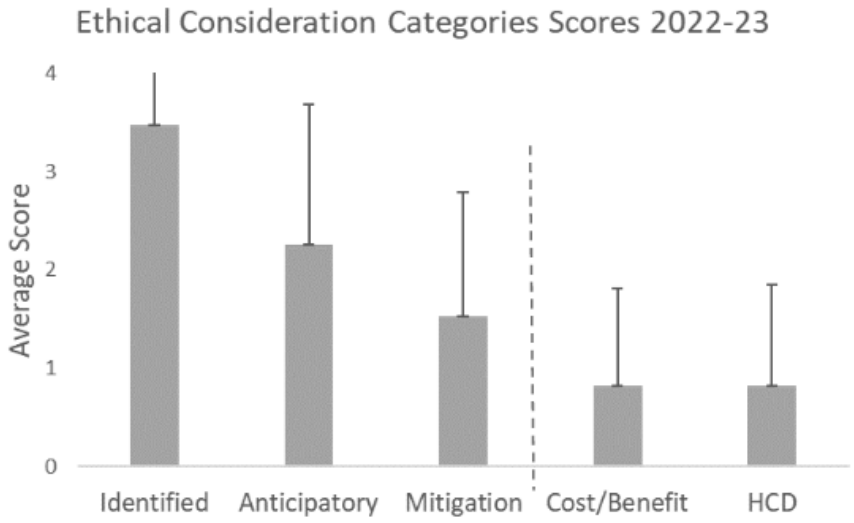


Figure 22. *Average scores of individual ethical considerations categories for 2022-23 BME MQP ethics statements. Dotted line indicates division between fundamental ethical considerations and higher level comparisons.*

Scoring distributions for higher-level grading criteria like *Cost/Benefit Analysis* and *Healthcare Disparities* remain right skewed, but compared to the prior year comparison, a greater proportion of student groups scored 3s and 4s, as seen in Figure 22. This is especially true for the healthcare disparities distribution, where in the prior year comparison only 4 student groups scored above a zero and none above a 2.

Overall, our analysis revealed that students in the full participation group consistently outperformed those evaluated in the prior year comparison (see Figure 23). Nearly 57% of all full participation testing ethics statements submitted were awarded full points for the *Identified* criteria, as opposed to only 1 out of 33 in the prior year comparison. In all categories of evaluation, both ABET and ethical consideration categories, ethics statements from the full participation testing scored higher on average with improvements ranging from +67% to +367% (see Tables 7 and 8).

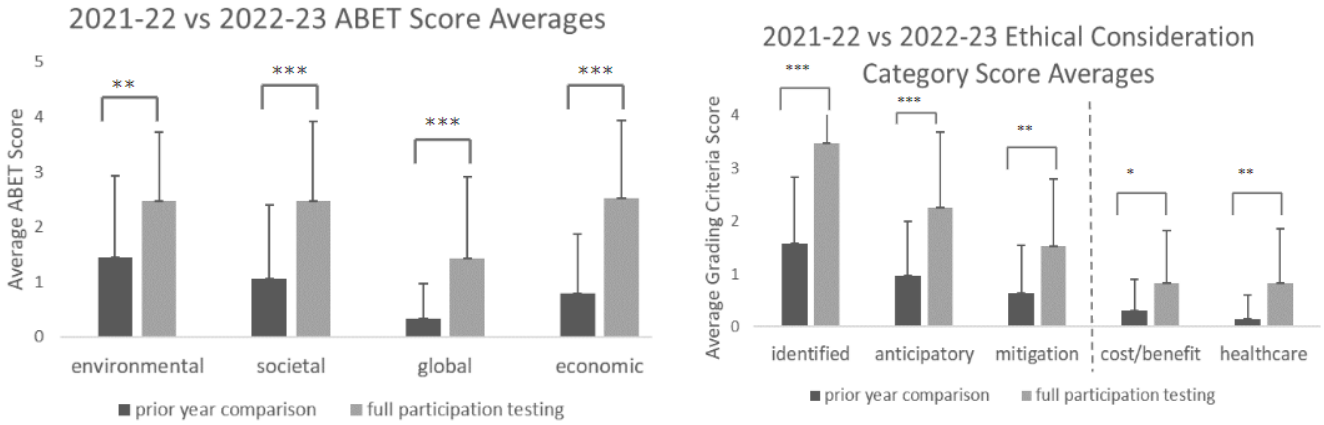


Figure 23. *Average score comparisons between 2021-22 and 2022-23 BME MQP ethics statements.* (* indicates $p < .05$, ** $p < .01$, and *** $p < .001$). *Dotted line indicates division between fundamental ethical considerations and higher level comparisons.*

Table 7. *Scoring comparisons between 2021-22 and 2022-23 BME MQP ethics statements (ABET criteria)*

ABET Category	**Prior year comparison average (out of 5 pts)**	**Prior year comparison standard deviation**	**Full participation testing average (out of 5 pts)**	**Full participation testing standard deviation**	**Average score improvement (absolute)**	**Average score improvement (percentage)**
Environmental	1.5	1.48	2.5	1.24	+1.0	+67%
Societal	1.1	1.34	2.5	1.44	+1.4	+127%
Global	0.3	0.65	1.4	1.47	+1.1	+367%
Economic	0.8	1.08	2.5	1.41	+1.7	+213%

Table 8. *Scoring comparisons between 2021-22 and 2022-23 BME MQP ethics statements (ethical consideration categories)*

Ethical Consideration Category	**Prior year comparison average (out of 4 pts)**	**Prior year comparison standard deviation**	**Full participation testing average (out of 4 pts)**	**Full participation testing standard deviation**	**Average score improvement (absolute)**	**Average score improvement (percentage)**
Identified	1.6	1.25	3.5	0.73	+1.9	+119%
Anticipatory	1.0	1.02	2.3	1.42	+1.3	+130%
Mitigation	0.6	0.90	1.5	1.27	+0.9	+150%
Cost/Benefit	0.3	0.59	0.8	0.98	+0.5	+167%
HCD	0.2	0.44	0.8	1.03	+0.6	+300%

A series of one-way ANOVAs tested differences in scores across the rubric criteria between the prior and current year's MQP groups. This test revealed that this year's ethics statements scored significantly higher than last year's ethics statements across all dimensions. See Table 9 for descriptive and test statistics. These statistical metrics confirm that the deviations in score are from populations with differing means, and that the likelihood of this data stemming from the same population is extremely small.

Table 9. *Statistical analysis and scoring comparisons between 2021-22 and 2022-23 BME MQP ethics statements for all grading criteria.*

Category	**Prior Year Average Score**	**Prior Year Standard Deviation**	**Full Participation Average Score**	**Full Participation Standard Deviation**	***F***	***p*-value**	**Cohen's *d***
Total	3.64	3.30	8.91	4.35	26.69	< .001	1.37
Environmental	1.45	1.48	2.48	1.24	7.38	< .01	0.75
Societal	1.06	1.34	2.48	1.44	14.20	< .001	1.02
Global	0.33	0.65	1.43	1.47	14.56	< .001	0.97
Economic	0.79	1.08	2.52	1.41	27.08	< .001	1.38
Identified	1.58	1.25	3.48	0.73	42.87	< .001	1.86
Anticipatory	0.97	1.02	2.26	1.42	15.76	< .001	1.05
Mitigation	0.64	0.90	1.52	1.27	9.35	< .01	0.80
Cost/Benefit	0.30	0.59	0.83	0.98	6.20	.016	0.65
HCD	0.15	0.44	0.83	1.03	11.27	< .01	0.85

Full Participation Feedback

After the iterations were made to the interactive guide, the MQP groups spent time completing the feedback survey providing our group with data and results that proved insightful in analyzing the effectiveness of the interactive guide and provided the groups with an outlet to share feedback and concerns regarding the project. The data collected from the survey will play a vital role in the future direction of the interactive guide, as multiple formats of questions including open-ended, multiple choice and Likert-scale allowed participants to assess the modules.

On average the survey took five minutes to complete and a total of n=30 students participated in the survey. The students who took the survey ranged from a variety of different project groups. Despite this, we have to recognize that some students may have completed the modules together.

Early in the survey, students are asked to rate their familiarity and knowledge of ethics and healthcare disparities prior to interacting and completing the module. As previously stated, students had the option to select an answer from 1-5, with 1 being “No knowledge of ethics and healthcare disparities" and 5 being “Extensive knowledge of ethics and healthcare disparities.” Most scores fell between a 3 and 4 with the average student scoring 3.5. Following this, students were then asked to grade their knowledge after completing the interactive guide in full. All of the students (n=30) scored higher in their understanding as most scores fell between a 4 and 5 with the average score of 4.06, a .56 point increase of knowledge gained. Students then concluded that their ethics statement fell between “Neither improved nor worsened” and “Somewhat improved” after using the interactive guide compared to if they had not done so resulting in an average of 3.69.

Students' overall experience with this module was also a key question. The question was structured similarly to others, as the options ranged from 1 being “Overall, the course was bad” to 5 being “Overall, the course was great”. The average grade from the students was a 3.22, showcasing that their overall experience was average. The students were then asked to rate their feelings based on the following statement “The Canvas course was helpful in the development of our MQP ethics statement.” The options ranged from 1 being “Strongly disagree” to 5 being “Strongly agree” and the average score was a 3.83. This fell between neither agreeing or disagreeing and somewhat agreeing. However, this is a point less than the score received from

just the pilot groups elaborating on the fact that the majority of students found this course to not have much of an impact. Furthermore, students were then asked to rate their feelings on another statement to judge the effectiveness “The Canvas course was clear and well-defined”. Using the same grading scale the students scored this a 4.8 with 16 indicating “Strongly agree.” Additionally, we can see that this score stayed constant after the iterations were made. Students were then asked a series of questions based on how long it took to go through the interactive guide, including the discussion with their advisor and how long they spent to write their ethics statements. On average, students stated that it took 50-60 minutes to go through the online modules (range: 10 to 90 minutes) and 60-80 minutes (range: 10 to 90+ minutes) for students to write and complete their ethics statements.

The last question of the 21 question survey is an open-ended question asking students to share any feedback or questions that they may have. After receiving 12 more responses from all MQP groups, to view the effectiveness of the scope of the project. Some suggestions were more in depth than others and provided useful information that should be considered. Honest feedback was critical and one student stated “much of this course arose more questions than it answered. It felt like it was not always applicable to our project. It also felt repetitive.” Another student believed that the information needed to be condensed in the interactive guide and that a hard deadline while preparing for presentation day was not pleasant. This feedback was informative in guiding the future of this project and will be further reviewed in the *Discussion*.

Discussion

The data collected in the full participation testing confirm that the incorporation of the interactive guide successfully improved the quality of BME MQP ethics statements in the year 2022-2023. In the submitted ethics statements we saw an average total score of 145% higher relative to the prior year comparison, with a *p-value* of < .001 between the two groups, indicating a statistically significant change in average score. Every individual grading category of the rubric, including both ABET and ethical consideration categories, saw similar higher scores and were confirmed to be statistically significant by *p-value*, *F*, and *Cohen's d*. The *Cohen's d* effect size for the total average score comparison was 1.37, indicating a large effect size, and the lowest effect size observed for an individual grading category was a 0.65. It should be acknowledged that within the scope of these ethics statements a perfect score is beyond expectations, as not all projects have topics that can be thoroughly applied to each grading category. Scores 3 or lower would be considered poor understanding and consideration. Using the rubric, a score of 8 or higher indicates a good grasp on ethical considerations for their project. The Interactive Guide was successful in guiding students to produce higher quality ethics statements than what was being produced without it.

These positive changes are consistent with the higher scores seen in previous BME ethics IQPs, *Education of Healthcare Disparities: Creating a Framework for Worcester Polytechnic Institute's Biomedical Engineering Department* and *A preliminary analysis of healthcare disparities curriculum at WPI* (Bushe et al., 2022) (Cordner et al., 2021). Without further iterative changes to the interactive guide, the quality of the content relative to other approaches is uncertain, but the presence of the interactive guide alone has a drastic effect on the higher scores of ethics statements. The delivery method and point of integration in the curriculum may vary,

however, higher scores in observed metrics were recorded after implementing the educational content for the previous IQP as well. While not as drastic, this effect was also observed in the 2021-22 *Education of Healthcare Disparities: Creating a Framework for Worcester Polytechnic Institute's Biomedical Engineering Department* IQP, where students who participated reported they felt that the content provided was helpful to their understanding of healthcare disparities (Bushe et al., 2022). The observations from the 2020-21 *A preliminary analysis of healthcare disparities curriculum at WPI* IQP indicated a severe lack of healthcare disparities education within the BME department at WPI (Cordner et al., 2021). These observations are consistent with the results of the prior year comparison as well as the full participation testing, where despite higher scores in the healthcare disparities category, in both groups the average scores for this section were lower than any other category evaluated.

After the initial pilot group testing, feedback received from the students and advisors guided iterations made to the interactive guide. It was suggested that advisor discussion questions were non-specific and did not aid in a meaningful discussion. In light of this suggestion, a checklist was provided for students and advisors, as well as project-specific questions to help guide the discussion. Additionally, it was suggested for the interactive guide to be a part of the syllabi for MQP projects, and for the modules to be given to students earlier in the school year. No iterations were made since the intention is to integrate the interactive guide into the WPI BME curriculum in the future and include it in the syllabi distributed at the beginning of the academic year, which was not feasible this year due to the timeline of our project. Feedback survey data from pilot groups suggested that the interactive guide was successful in aiding students to create a thorough ethics statement and that students enjoyed the various forms of instructional material, which is consistent with previous literature suggestions

to incorporate different formats of learning (Burton, 2022). Data also proved that the short format of the interactive guide was appreciated as students expressed time constraints in completing the interactive guide. This feedback is also consistent with previous data that suggests information to be broken up into 5-7 minute chunks *(UNF Engaging Students In Canvas*, n.d.).

After the iterations were made, the interactive guide was distributed to all the 2022-23 BME MQP groups and 23 ethics statements were received for scoring. Our rubric evaluation revealed an average score of 8.9 out of 20, with a standard deviation of 4.35. Analysis of scoring within each ABET category shows higher scores for all ABET categories, with the most higher scores in the *Economic* category. While higher scores were produced, the data shows that of the four ABET categories, students struggled to score points for the *Global* category the most. Scoring distributions for each grading criterion revealed students achieved higher scores for the *Identified* criterion, as the average score increased from a 1.6 in the prior year comparison to a 3.5 out of 4 in the full participation testing. Nearly 57% of all full participation testing ethics statements submitted were awarded full points for the *Identified* criteria, as opposed to only 1 out of 33 in the prior year comparison. The categories of *Anticipatory* and *Mitigation* also saw higher scores, but unlike the ABET categories, the score frequencies are fairly even between scores. Scoring distributions for *Cost/Benefit Analysis* and *Healthcare Disparities* remain right skewed, but compared to the prior year comparison, a greater proportion of student groups scored 3s and 4s. Overall, our analysis revealed that students in the full participation group consistently outperformed those evaluated in the prior year comparison. In all categories of evaluation, both ABET and ethical consideration categories, ethics statements from the full participation testing scored higher on average with higher scores ranging from +67% to +367%. Statistical analysis

proved the interactive guide was successful in aiding BME MQP students to write a thorough ethics statement compared to the quality of ethics statements previously being created. The data resulted in a *p-value* of < .001 between the scores of the 2021-22 statements and 2022-23 statements, proving a significant increase in scores. For each scoring category, *F* greater than 1 and *Cohen's d* greater than 0.65 also confirm statistical significance and large effect size. Feedback from full participation students was consistent with the feedback received from the pilot group students, with the majority of suggestions revolving around distributing the interactive guide earlier in the academic year, which is discussed further in *Future Recommendations*.

Limitation

While the interactive guide was able to help increase the scores of the ethics statements the pilot groups wrote, one limitation of our project was that we had to implement the interactive guide incongruously with how it would ideally be implemented throughout the academic year, which is detailed further in the *Future Recommendations* section below.

There were also limitations related to advisor expertise and motivation. Although the BME department has some level of familiarity with ethics, there are no measures in place to ensure uniform understanding across all faculty members. Consequently, the advisor discussion section of this module was restricted as advisors lacked comprehensive knowledge when it came to an in-depth exploration of ethics. Additionally, it was noted that the advisors do not place much weight on the ethics statement of the MQP paper and thus do not push their group to spend much time on this section.

Evaluator bias also limits the validity of the scores given to MQP ethics statements, since the evaluators are also part of the IQP group and knew the purpose of the modules, they may have implicitly been biased toward giving lower scores to the prior year comparison and higher scores to the 2022-2023 MQPs so that the results would reflect favorably for the Interactive guide.

Future Recommendations

For a more effective future implementation of the interactive guide, a number of improvements may be made. The most important change is implementing these modules during the first term of the MQP, when project planning is the focus. The timeline of BME MQPs can be seen in Figure 24 and the major focuses for each of the 4 terms are as follows:

- A term: time spent on logistics and designing the best approach to the project
- B and C term: focus on building, troubleshooting, and testing the project
- D term: most of the paper is written

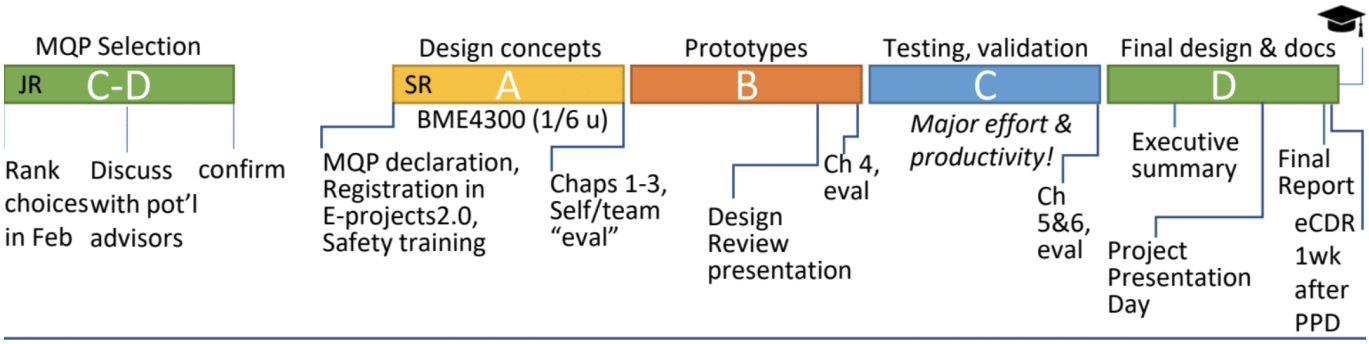


Figure 24. *Timeline of WPI BME MQP projects.*

For the pilot testing to take place and allow sufficient time to incorporate feedback and improve the interactive guide, pilot group participation was required during C term. This posed an issue as many MQP teams were still troubleshooting their project in C term, and did not have

all the necessary information to include in their ethics statements. To accommodate this, deadlines for pilot groups were delayed multiple times, preventing multiple iterations of the interactive guide. In the future, another iteration should be completed to include more recommendations and expertise from students and advisors to further increase effectiveness of the Interactive Guide.

Introducing another component to the MQP at a late stage made it difficult to recruit participating MQP teams. Although intended as a helpful tool, several teams were hesitant to include an extra element in their project or allocate time away from its execution. Going forward it would be best to introduce this tool to MQP groups in A term as a component of the project requirements, allowing students enough time to use the online learning module to the fullest extent. By introducing the concept of ethics and health disparities in the preparation phase, students will not only have more time to work on their ethics statements, but may let the educational content influence how they plan to complete their project. Identifying potential ethical dilemmas in the early phases of their capstone and coming up with a new method to avoid the problem would be great preparation for making ethical decisions in the real world. However, early focus on ethical thinking should not be a replacement for continual integration of ethical thinking into the MQP process, and reflection in both the mid and final portions of the project are equally important.

Much of the feedback gained from the full participation cohort focused on the differences between the suggestions for ethics statements in the Interactive Guide created through this project and the writing guide given to BME MQP students to help format their MQP Paper. It is recommended that the BME MQP writing guide be updated to better reflect the process for ethics statements and consideration of healthcare disparities outlined in the Interactive Guide,

since the findings of this project indicate better results than what was achieved from the writing guide recommendations that were implemented alone the year prior.

Additionally it may be beneficial to include greater advisor involvement in the process for future groups. Currently, advisors only need to participate in the guided discussion portion of the modules, but there may be benefits to increasing their role and knowledge in the Interactive Guide. Implementing a secondary module for advisor preparation or having a greater number of activities with advisor participation may be the key to maintaining longevity of these educational modules. Because advisors are long-term members of the WPI community with multiple years of MQP experience, increasing advisor involvement and encouraging advisors to implement the modules themselves may increase the longevity of our product and encourage use by future undergraduates. Another consideration could be to implement an ethics curriculum for MQP advisors at WPI. Based on the advisor feedback, many of the advisors were hesitant to lead an ethics discussion as they were not confident in their knowledge on ethics, therefore, incorporating an ethics education for advisors may help to generate more meaningful discussions. However, the largest obstacle for either recommendation is whether the advisors have the time, willingness, and energy to take a more active role in the modules and further their ethics education.

There are also iterative changes to the educational content itself that may improve the modules. For example, increasing the emphasis on healthcare disparities within the modules may increase student's consideration for ethical problems within the healthcare system. By integrating examples of considerations for healthcare disparities into all sections of the modules, students could better understand how healthcare disparities relate back to ethics and how they are caused

and combatted. These examples to improve the focus on healthcare disparities education could potentially improve the modules' utility in preparing students for their future careers.

Future research should recruit blind evaluators to apply the rubric to ethics statements without knowing whether the group had or had not used the modules to produce their statements. This would limit evaluator bias and help better support the claims of this paper about the ability of the Interactive Guide to be effective in helping students craft ethics statements.

Other BME programs or other engineering departments may also benefit from these educational modules. Since all WPI undergraduate students must complete an MQP, a comprehensive ethics education could be impactful for other majors as well. Although this interactive guide was customized for BME majors, it could be modified to suit the needs of other majors at WPI. Biological agents, patient interactions, and other healthcare related topics may apply well to other disciplines at WPI, such as biochemistry and biology/biotechnology, whose students could also benefit from healthcare disparities discussions. The information in these modules can be applied to many topics, but in order to effectively prepare students for ethical decision making in any career of their choice, a more targeted educational approach that can be implemented autonomously may be required.

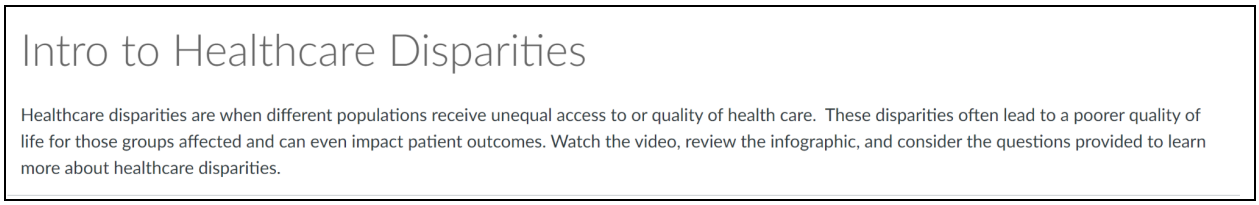
Conclusion

In previous year's BME MQPs, students were not properly addressing ethical concerns, and would use the ethics section of their MQP papers to justify the decisions made for their project rather than consider impacts, both good and bad. Students were hesitant to discuss any potentially negative effects of their projects. This IQP created the interactive guide to help students fulfill all of the ABET ethics requirements, as well as address any concerns related to healthcare disparities. After completing the interactive guide, students had the tools needed to

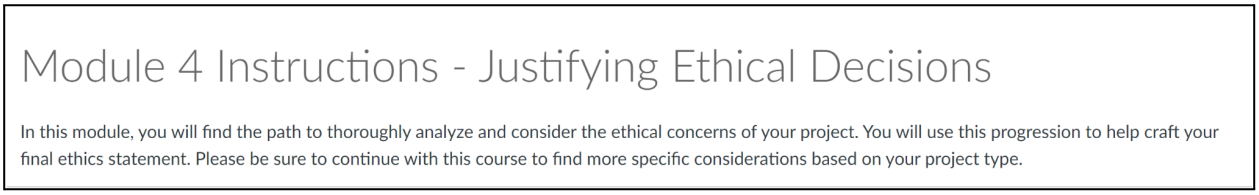
create a complete ethics statement. After the pilot group testing and full participation testing were completed and analyzed, the scores of the ethics statements had increased compared to the prior year. The average score of the prior 2021-2022 MQP ethics statements was a 3.64 out of 20, while the average score of the pilot groups was a 10.01 out of 20. After some improvements were made to the interactive guide, it was given to all of the BME MQP groups for the year 2022-2023 as a tool to use to complete their ethics statements. 23 groups opted to use the interactive guide, and the average score for their ethics statements was an 8.91 out of 20, a significant increase from the prior year comparison. This increase demonstrates the ability of the interactive guide to aid students in creating better ethics statements.

In creating the interactive guide we aimed to implement an autonomous tool for BME MQP groups to use that helps them better understand the ethical considerations of their project, as well as helping them include all of these considerations in their writing. The interactive guide serves as a sustainable solution to help the BME department at WPI ensure their senior capstone design students are given the resources to help them thoughtfully consider ethical implications going forward, and is shown to be effective through the increase in score of those who chose to participate. To improve the use of this tool for both advisors and students going forward, the interactive guide would benefit from advisors participating in an educational module on ethics, which would aid in the discussion between advisors and students, and also from earlier implementation of the guide at the beginning of MQP projects.

Appendix



Appendix A: Module 3 Introduction to Healthcare Disparities Page.



Appendix B: Module 4 Instructions.

	Identified	Anticipatory	Mitigation	Cost/Benefit Analysis	Healthcare Disparities	
Environmental						0
Social						0
Global						0
Economic						0
	0/1	0/1	0/1	0/1	0/1	0

Environmental: mentions value of human or biological life or the environment
Social: reflection on the moral dimensions of social structures, systems, issues, and communities; topics include distribution of economic goods, research on human subjects, animal rights, etc.
Global: reflects on global considerations; child labor, scarce resources, climate change, global trade, medical tourism, humanitarianism etc
Economic: reflects on distribution of wealth, treatment of poor, benefit vs cost relationship

Identified: Establishes/indicates an understanding of ethics in the scope of their project
Anticipatory: Establishes deeper level understanding by demonstrating how the project will impact potential consequences
Mitigation: Complete understanding of ethics in the lens of the project. The group plans to avoid potential ethical issues that could arise in the future
Cost/Benefit Analysis: Compare costs to the benefits of the given project. Many projects will include the lesser of the two eveils (Human life vs nature)
Healthcare Disparities: Preventable differences in the burden of disease, injury, violence, or in opportunities to achieve optimal health experienced by socially disadvantaged racial, ethnic, and other population groups, and communities

Appendix C: Baseline Testing Rubric.

Example MQP Ethics Statements Grading

The following is an example ethics statement for a sit-to-stand device for elderly populations. Please take a look at what sections identify, anticipate and mitigate ethical issues as well as tools used to justify their ethical decisions. The rubric shows how well the team included all the necessary ethical reasoning to create a full, complete ethics statement. Below most of the sections are noted on how they could have been improved.

	Identified	Anticipatory	Mitigation	Cost/Benefit Analysis	Healthcare Disparities	Total
Environmental	1	1	1	0	0	3
Social	1	1	1	0	0	2
Global	1	1	1	1	1	5
Economic	1	1	0	1	1	3
Total						13/20

Environmental:

Often, individuals who struggle to stand also have difficulties walking around and do not leave their houses frequently [16]. As a result, they use a lot of electricity while at home. This device aims to strengthen the user's legs for them to be able to stand up, which is a stepping stone to gaining more mobility. This will give a person the ability to walk to many places instead of driving, which reduces the strain on the environment. Additionally, the product converts the force from the user's arms to a lifting force on the seat without any additional external input. Any material used in the manufacturing of the device (for example, plywood, 303 stainless steel, or ABS) is readily available. Because the UFS Press Machine must be manufactured in a factory and then shipped to customers, power factories and manufacturing plants will experience an uptick in resource usage. Medical device manufacturers will also undergo an increase in carbon footprint as a result of making this product. However, the overall production of our device will have a fairly negligible impact on the greater environment.

- In order to get a cost/benefit analysis they could have said that the negligible impact on the environment is outweighed by the benefit of independence for elderly patients.
- To get a healthcare disparities point they could have mentioned the impact of sourcing materials for the device on the health of local populations.

Social:

Although our device targets geriatric individuals who struggle to stand by themselves, others (including families and the general public) will be positively impacted by this device. As they watch and experience their loved ones gaining back strength and subsequently their independence, families can have more peace of mind because the likelihood of an accident decreases. They are also saving time and preventing stress because they do not need to be dutiful about providing for their family member. Furthermore, as individuals use this device, they are helping to market to their family and friends who may have the same problems but have not yet found an effective solution. They may be much more inclined and motivated to try out this device and reap the benefits. Those who interact with or see the elderly on any particular day often feel the inclination to help them or make sure they are safe, whether it is a conscious effort or not. This sentiment is greatly reduced when these people are standing by themselves and moving around independently. Overall, society as a whole will have reduced worry for the elderly population as a result of this product.

- To incorporate healthcare disparities they could have mentioned how they plan to market and create the product for people other than just the elderly to have access to it.
- Another way to incorporate healthcare disparities would be to discuss how the price of the device impacts who can get it. Will this only benefit wealthy elderly people, which widens the healthcare disparity between poor and wealthy populations?

Global:

The UFS Press Machine is a product that would be useful worldwide, given the increasing proportion of elderly people in the overall population. In 2016, 8.5% of the population is 65 years or older, and that number is predicted to grow to close to 17% by 2050 [84]. With so many elderly people in today's world and fewer people to take care of them, a device that gives people independence while standing up will be of huge importance. Therefore, we see a need for this product in the global market. However, when expanding to encompass the entire world as potential customers, we need to take care in understanding each culture's treatment, lifestyle, and condition of the elderly population. In our research thus far, we have been concentrating on factors affecting the geriatric population in the United States, one major issue being the obesity epidemic in those over the age of 65. In the US, 37.5% of elderly males and 39.4% of elderly females are classified as obese based on their body mass index. This is partially due to genetics, as body fat naturally increases over time before beginning to decline in a person's 80s, and is also seen in countries such as Canada and the United Kingdom. However, not all countries have abnormally high obesity rates as seen in the aforementioned three. For example, the populations of Japan and Korea have extremely low percentages of people classified as obese [86]. Therefore, when advertising in these countries, we have to take care in ensuring that this product is framed as an assistive device to help people feel more comfortable and safe in their everyday life, rather than something that a patient may need when they become unable to perform physical activities. Another aspect of the elderly population in the US we focused on was the rising nursing home population. These establishments are understaffed and filling fast, and need a reliable product that allows their residents to stand without needing help from a staff member. However, not all countries house a large number of their elderly in nursing homes. Notably, Italy, France, Sweden, and Japan do not have many facilities strictly dedicated to the care of the elderly population [87]. This may be in part due to infrastructure, but it is mainly a result of the different cultures observed in these countries. Western countries like the US and UK have very individualistic cultures, putting more emphasis on the person rather than the collective good. The large exception to this is France, which has laws in place requiring families to look after their elderly members. Latin and Mediterranean cultures are just the opposite, putting emphasis on family and having multiple generations living in the same household. Asian cultures such as China and Korea put a huge responsibility on people to care for their parents [88]. In these countries where family and respect for the elderly are put before the individual, we need to make sure that we are not advertising our product to be a replacement for family care. Instead, we need to frame it as being a supplement to a loving family that can help the user feel more empowered, independent, and able to keep up with their younger family members. We need to really understand the role of our device and acknowledge that it cannot fill the role of good family and friends.

Economic:

Nowadays, it is possible to get nearly everything through means of delivery: groceries, household appliances, fast food, clothing, and even cars. However, there are still numerous businesses that do not offer delivery options. With strengthened legs, individuals may be able to better support these businesses as a result of increased mobility. Assisted living organizations would also be able to redistribute funds to admit more individuals or buy more materials. This is because there would be a slightly lower demand for helpers as a result of the increased independence of patients. Similarly, any hired at-home nurse would not have to check in on an individual as often and thus anyone employing the nurse could spend less money. Although purchasing this device would be initially costly, it would be one large expense up front and only small charges afterward, if necessary. These would only be if the individual needs to buy an adjustable torsion spring component. Despite this, future costs could be reduced as a result of fewer falls and hospital visits.

- To get the point for healthcare disparities the group could have mentioned the negative effects of inaccessibility issues such as the higher cost to deliver groceries/goods and how much could be saved if the users had the freedom to shop for themselves.
- For mitigation, they could have mentioned a plan to lower the cost of the product to prevent inaccessibility to poorer populations

Appendix D: Graded Past MQP Statement.

Societal

- Is your project easily accessible to those it is targeted for?
- If misused will your project affect more than those using it?
- Could your project be exploited for the gain of one person or group?

Environmental

- Are you using a finite resource?
- Are the resources being used ethically sourced?
- Will your project contribute a significant amount of waste?
- Are any living organisms other than your patient affected by your project?

Economic

- How will inflation contribute to the availability of your project?
- Will your project follow the laws and regulations set by the country?
- What are the standards set for those working on your device/project for manufacturing?
- How will this contribute and/or harm the economy?
- Will this product be affordable to the consumer?

Global

- If production is done overseas, are the workers' conditions sacrificed to save on production costs?
- How will trade patterns between countries affect the product?
- Will your project only be available in some countries?

Healthcare Disparities

- Who is the primary stakeholder?
- Does your project favor a specific group? Is it bias-less?
- Who uses this product? Who is this product used on?
- How accessible is this? Is it affordable? Will this be available from multiple providers?
- How does this compare to current products/research? Does it fill a need?
- Does it address the needs of demographics with unique health concerns?

Appendix E: Advisor Discussion Questions.

What is ABET

At WPI, the BME department is certified by the Accreditation Board for Engineering and Technology (ABET). In the BME department, MQP ethics statements partially fulfill this requirement.

The ABET requirements are as follows:

(1). An ability to identify, formulate, and solve complex engineering problems at the interface of engineering and biology by applying principles of engineering, science, and mathematics

(2). An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

(3). An ability to communicate effectively with a range of audiences

(4). An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

(5). An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

(6). An ability to develop and conduct appropriate experimentation, analyze and interpret data from living and non-living systems, and use engineering judgment to draw conclusions

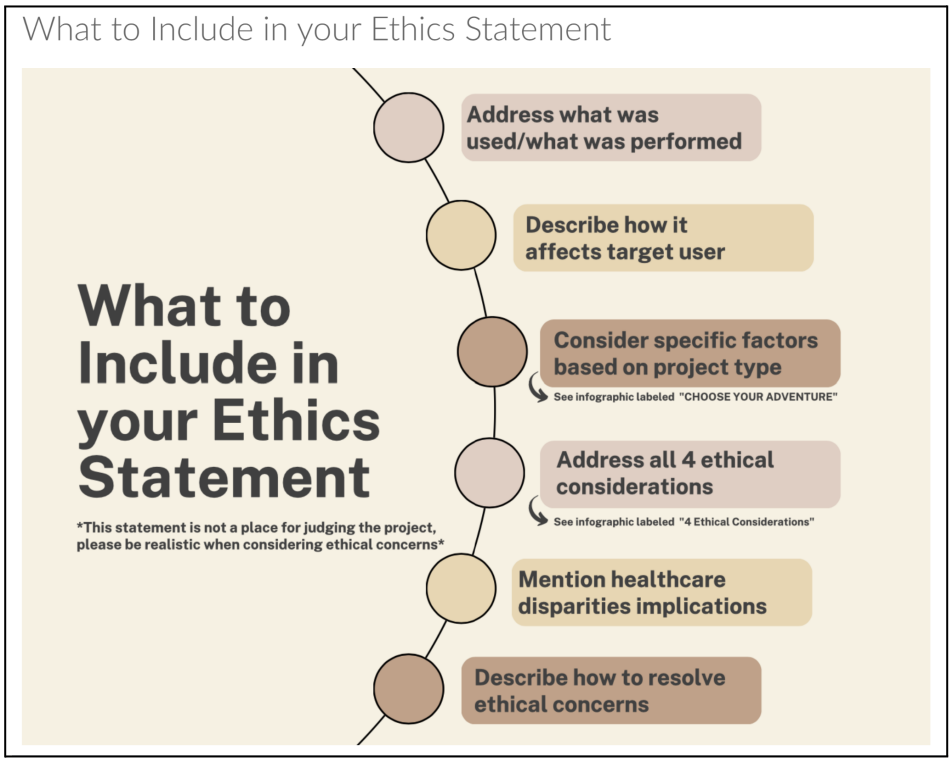
(7). An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

(8). An understanding of biology and physiology

(9). An ability to address the problems associated with the interaction between living and non-living materials and systems.

The bullet point to pay attention to is #4. Ethics statements need to consider global, social, environmental, and economic factors in order to be deemed complete. Papers need to consider and touch upon each factor in order to consider all ethical implications.

Appendix F: ABET Requirements for the BME Department given in Advisors Module.



Appendix G: What to include in your Ethics Statement Infographic.

Canvas Course Feedback - BME MQP Ethics Statements

Q1 Name

_____

Q2 WPI Email

_____

Q3 MQP Group (please put your advisor's name, followed by the MQP project title)

_____

Q4 Please copy and paste the ethics statement you developed using the Canvas course.

_____

Q5 Have any of your WPI classes delivered content on ethics and healthcare disparities?

- ○ Yes (1)
- ○ No (2)

Q6 On a scale of 1-5, how would you rate your knowledge of ethics and healthcare disparities BEFORE interacting with the Canvas course?

	1 - I did not know what ethics nor healthcare disparities were. (1)	2 - I knew a little bit about ethics and healthcare disparities. (2)	3 - I knew an average amount about ethics and healthcare disparities. (3)	4 - I knew a lot about ethics and healthcare disparities. (4)	5 - I knew an extensive amount about ethics and healthcare disparities. (5)
My knowledge on ethics and healthcare disparities BEFORE interactive with the Canvas course. (1)	○	○	○	○	○

Q7 On a scale of 1-5, how would you rate your knowledge of ethics and healthcare disparities AFTER interacting with the Canvas course?

	1 - I do not know what ethics nor healthcare disparities are. (1)	2 - I know a little bit about ethics and healthcare disparities. (2)	3 - I know an average amount about ethics and healthcare disparities. (3)	4 - I know a lot about ethics and healthcare disparities. (4)	5 - I know an extensive amount about ethics and healthcare disparities. (5)
My knowledge on ethics and healthcare disparities AFTER interactive with the Canvas course. (1)	○	○	○	○	○

Q8 On a scale of 1-5, how would you rate the Canvas course overall?

	1 - Overall, the course was bad. (1)	2 - Overall, the course was okay. (2)	3 - Overall, the course was average. (3)	4 - Overall, the course was good. (4)	5 - Overall, the course was great. (5)
The Canvas course overall. (1)	○	○	○	○	○

Q9 On a scale of 1-5, how would you rate the ethics statement you and your group created using the Canvas course.

	1 - Our ethics statement was bad. (1)	2 - Our ethics statement was okay. (2)	3 - Our ethics statement was average. (3)	4 - Our ethics statement was good. (4)	5 - Our ethics statement was great. (5)
Rating of the ethics statement created using the Canvas course. (1)	○	○	○	○	○

Q10 How different is your ethics statement after using the Canvas course vs if you had not used the Canvas course?

	Extremely worsened (1)	Somewhat worsened (2)	Neither improved nor worsened (3)	Somewhat improved (4)	Extremely improved (5)
Rating of your ethics statement after using the Canvas course vs without it. (1)	○	○	○	○	○

Q11 Please rate your feelings on the statement below.

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
The Canvas course was a good experience. (1)	○	○	○	○	○

Q12 Please rate your feelings on the statement below.

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
The Canvas course was helpful in the development of our MQP ethics statement. (1)	○	○	○	○	○

Q13 Please rate your feelings on the statement below.

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
The Canvas course was clear and well-defined. (1)	○	○	○	○	○

Q11 Please rate your feelings on the statement below.

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
The Canvas course was a good experience. (1)	○	○	○	○	○

Q12 Please rate your feelings on the statement below.

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
The Canvas course was helpful in the development of our MQP ethics statement. (1)	○	○	○	○	○

Q13 Please rate your feelings on the statement below.

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
The Canvas course was clear and well-defined. (1)	○	○	○	○	○

Q16 How much time did it take you to write your ethics statement?

- ○ Less than 10 minutes (1)
- ○ 10 to 20 minutes (2)
- ○ 20 to 30 minutes (3)
- ○ 30 to 40 minutes (4)
- ○ 40 to 50 minutes (5)
- ○ 50 to 60 minutes (6)
- ○ 60 to 70 minutes (7)
- ○ 70 to 80 minutes (8)
- ○ 80 to 90 minutes (9)
- ○ More than 90 minutes (10)

Q17 When would you recommend this Canvas course be deployed to BME MQP students?

- ○ Before A-Term (1)
- ○ A-Term (2)
- ○ B-Term (3)
- ○ C-Term (4)
- ○ D-Term (5)

Q18 When would you recommend BME MQP groups to write their ethics statements?

- ○ Before A-Term (1)
- ○ A-Term (2)
- ○ B-Term (3)
- ○ C-Term (4)
- ○ D-Term (5)

Q19 How likely would you be to recommend this course to another BME MQP student?

	Extremely unlikely (1)	Somewhat unlikely (2)	Neither likely nor unlikely (3)	Somewhat likely (4)	Extremely likely (5)
Likelihood of recommending this cause to another BME MQP student. (1)	○	○	○	○	○

Q20 Could you see this Canvas course being helpful to non-BME MQP groups?

- ○ Yes (1)
- ○ Maybe, if the curriculum was adapted to other majors. (2)
- ○ No (3)

Q21 Any other feedback or suggestions would be appreciated!

_____

Appendix H: The interactive guide feedback survey.

References

2022 National Healthcare Quality and Disparities Report | Agency for Healthcare Research and Quality. (n.d.). Home | Agency for Healthcare Research and Quality. Retrieved April 20, 2023, from https://www.ahrq.gov/research/findings/nhqrdr/nhqdr22/index.html

ABET Accreditation. (n.d.). Worcester Polytechnic Institute (WPI). Retrieved April 20, 2023, from https://www.wpi.edu/academics/departments/biomedical-engineering/accreditation

About | Khan Academy. (2008). Khan Academy. Retrieved April 20, 2023, from https://www.khanacademy.org/about

About ABET. (n.d.). ABET | ABET Accreditation. Retrieved April 20, 2023, from https://www.abet.org/about-abet/

Applied Ethics - Ethics Unwrapped. (n.d.). Ethics Unwrapped; https://www.facebook.com/EthicsUnwrapped. Retrieved April 20, 2023, from https://ethicsunwrapped.utexas.edu/glossary/applied-ethics.

BME Code. (2004, February). WPI BME Documents. https://www.wpi.edu/sites/default/files/docs/Departments-Programs/Biomedical-Engineering/BMEethcis.pdf

Burton, C. (2022, July 17). *How To Make Online Courses More Engaging & Effective For Students*. Thinkific; https://www.facebook.com/Thinkific. https://www.thinkific.com/blog/make-online-learning-more-engaging/

Bushe, K., Soucy, H., Serebrennikova, L., Billiar, K., & Rodriguez, A. (2022). *Education of Healthcare Disparities: Creating a Framework for Worcester Polytechnic Institute's Biomedical Engineering Department*. Retrieved April 20, 2023, from https://digitalwpi.wpi.edu/pdfviewer/f1881q06m

Center for Leadership and Ethics. (n.d.). McCombs School of Business. Retrieved April 20, 2023, from https://www.mccombs.utexas.edu/centers-and-initiatives/center-for-leadership-and-ethics/

Cordner, L., Hankaoui, S., O'Connor, D., Pollock, E., Wofford, B., & Billiar, K. (2021). *A preliminary analysis of healthcare disparities curriculum at WPI*. Retrieved April 20, 2023, from https://digitalwpi.wpi.edu/pdfviewer/t722hc760

Disparities | Agency for Healthcare Research and Quality. (n.d.). Home | Agency for Healthcare Research and Quality. Retrieved April 20, 2023, from http://www.ahrq.gov/topics/disparities.html

FuseSchool - About Us. (n.d.). FuseSchool. Retrieved April 20, 2023, from https://www.fuseschool.org/

Health Disparities | Healthy Aging | CDC. (n.d.). Centers for Disease Control and Prevention. Retrieved April 20, 2023, from https://www.cdc.gov/aging/disparities/index.htm

Hedge, A., & Hewett, B. (2020, October 22). *Examining effectiveness of online teaching modules on Developmentally Appropriate Practices (DAP) for guiding young children's behavior: student and instructor perspectives: Journal of Early Childhood Teacher Education: Vol 42, No 1*. Taylor & Francis. https://www.tandfonline.com/doi/abs/10.1080/10901027.2020.1781714

HHS Action Plan to Reduce Racial and Ethnic Health Disparities. (n.d.). A Nation Free of Disparities in Health and Health Care. Retrieved April 20, 2023, from https://www.minorityhealth.hhs.gov/assets/pdf/hhs/HHS_Plan_complete.pdf

Jackson, X., Jasensky, Z., Liang, V., Moore, M., & Rogers, J. (2015). A Joint Venture Approach in Teaching Students How to Recognize and Analyze Ethics. https://www.wpi.edu/academics/undergraduate/major-qualifying-project/project-search.

Jones, C. (2010, February 10). *The moral problem of health disparities - PubMed*. PubMed. https://pubmed.ncbi.nlm.nih.gov/20147677/

Major Qualifying Project. (n.d.). Worcester Polytechnic Institute (WPI). Retrieved April 20, 2023, from https://www.wpi.edu/academics/departments/biomedical-engineering/major-project#:~:text=The%20Major%20Qualifying%20Project%20%28MQP%29%20is%20a%20high-level,what%20you%20will%20find%20in%20your%20professional%20life.

Morden, N., Chyn, D., Wood, A., & Meara, E. (2021, July 22). *Racial Inequality in Prescription Opioid Receipt — Role of Individual Health Systems* . The New England Journal of Medicine. https://www.nejm.org/doi/full/10.1056/NEJMsa2034159

Nezafati, M. (2020, October). *wip: Integration of inclusive mindset in a middle-year biomedical*. https://peer.asee.org/wip-integration-of-inclusive-mindset-in-a-middle-year-biomedical-engineering-course-a-study-over-healthcare-disparities-via-story-driven-learning.pdf

Nielsen, J. (2021, November 7). *6 Environmental Benefits of Online Learning That Will Blow Your Mind - Sustainable Business Toolkit*. Sustainable Business Toolkit. https://www.sustainablebusinesstoolkit.com/social-and-eco-benefits-of-online-learning/

Oxford Learner's Dictionaries. (n.d.). Oxford Learner's Dictionaries | Find Definitions, Translations, and Grammar Explanations at Oxford Learner's Dictionaries. Retrieved April 20, 2023, from https://www.oxfordlearnersdictionaries.com/

Resnik, D. (n.d.). *What Is Ethics in Research & Why Is It Important?* National Institute of Environmental Health Sciences. Retrieved April 20, 2023, from https://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfm

Shamsi, H., Almutairi, A., Mashfari, S., & Kalbani, T. (2020, April 30). *Implications of Language Barriers for Healthcare: A Systematic Review - PMC*. PubMed Central (PMC). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7201401/

Sim, W., Lim, W., Ng, C., Chin, Y., Yaow, C., Cheong, C., Samarasekera, D., Devi, K., & Chong, C. (2021, August 31). *The perspectives of health professionals and patients on racism in healthcare: A qualitative systematic review - PubMed*. PubMed. https://pubmed.ncbi.nlm.nih.gov/34464395/

Telleil, Yunus Dogan. Personal Interview. 10 December 2022.

UNF Engaging Students In Canvas. (n.d.). UNF: UNF Homepage. Retrieved April 20, 2023, from https://www.unf.edu/cirt/services/id/bestpractices/engaging-students-in-canvas.aspx

Vasquez, M., Andre, C., Shanks, T., Meyer, S. J., & Meyer, M. (n.d.). *What is Ethics? - Markkula Center for Applied Ethics*. Home - Santa Clara University. Retrieved April 20, 2023, from https://www.scu.edu/ethics/ethics-resources/ethical-decision-making/what-is-ethics/

Vasquez, M., Marte, O., Barba, J., & Hubbard, K. (2017, August 28). *An Approach to Integrating Health Disparities within Undergraduate Biomedical Engineering Education | SpringerLink*. SpringerLink. https://link.springer.com/article/10.1007/s10439-017-1903-8#Sec7