## DESIGNING FOR *ETHICAL MATHEMATICS CONSCIOUSNESS*: A SYNTHESIS OF FINDINGS FROM A DESIGN BASED RESEARCH PROJECT EXPLORING HOW EDUCATORS MAY DESIGN FOR STUDENTS’ ETHICAL REASONING IN DATA SCIENCE

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The accumulation of data and lack of ethical guidance for managing the scale of personal information collected on a daily basis is arguably the greatest concern of the modern age (D’Ignazio et. al., 2020) and has significant implications for education. Given the newfound desire to process such data, the lack of qualified data scientists available has positioned individuals with advanced statistical, computational, coding knowledge as a commodity for corporations globally. As a result, it has been estimated that the majority of the jobs that will be available to students in the near future do not exist, and that many of these jobs will be in the data science field (Darling-Hammond, 2015). Importantly, every element of data science, from collection to analysis to enactment, includes distinct mathematical and statistical reasoning and critical thinking skills, while coding procedures and languages (e.g., Python, C++, Java, etc.) are grounded in algorithmic and logic-based thinking (Matthews, 2019). As such, the responsibility for the development of a data science workforce lies, at least partially, within the mathematics education community (Chiodo et al., 2019; Register et al., under review).

Beyond developing a data literate workforce, the impetus for a data science education is intimately connected to the global influence of BDA. The emergence of data science as a means to predict a myriad of outcomes and behaviors has led to its all-encompassing dispersion in society, influencing education, industry, politics, policy, and our everyday lives, having significant consequences for individuals and social groups in society. In particular, the algorithms developed through data science methods are often used as decision making tools for policy-makers in society and eligibility systems for social programs (O’Neil, 2016). While advancements in health care and an improved consumer experience reflect some of the benefits of BDA, it has been argued that its societal costs disproportionately affect individuals from historically oppressed groups (Benjamin, 2019; D’Ignazio et al., 2020; Eubanks, 2018). Therefore, beyond the impetus for a data literate global population is the necessity to foster critically conscious ethical dispositions both within the data science field and the general public, in order to safeguard against the negative effects of BDA.

**Purpose**

The purpose of this chapter is to provide an overview of our attempts to understand how we might design for ethical reasoning and decision making in the mathematical disciplines for a just and equitable future with an emphasis on data science. In particular, we argue that in the age of globalization and BDA, we must prioritize students’ development of *Ethical Mathematics Consciousness* (EMC), that is an *awareness that human beings do mathematics; thus, there are potential ethical dilemmas and implications of mathematical work which may affect entities at the individual, group, societal, and/or environmental level.* Drawn from Freirean notions of *critical consciousness*, and Kokka’s (2020) definition of *Critical Mathematics Consciousness (CMC),* EMC includes *sociopolitical, ecological, and communicative mathematical awarenesses, and a willingness and commitment to act* (i.e., *ethical mathematics agency)* (Andersson et al., 2022; Stephan et al., 2020; Register et al., 2021; Register, under review)*.*

In Fall of 2019, we established goals for a large Design Based Research (Bakker et al., 2014; Cobb et al., 2003) project for the purposes of understanding how we might develop students’ EMC. In addition to data science industry members, the design team consists of individuals from higher education with expertise in critical mathematics education, critical statistics education, ethics of Big Data, data science methods, systems and informatics, and teaching with technology. The project, at this time, consists of the following outputs:

* The Ethical Reasoning in Mathematics Principles (ERiM) Framework that offers potential ethical contexts and considerations for students to explore in the mathematical disciplines (Register et al., 2021; Stephan et al., 2020);
* 3 pilot task-based interview studies and corresponding tasks designed from the ERiM principles (Andersson et al., 2022; Register et al., 2021; Stephan et al., 2020);
* The initial design and analysis of an introductory Ethical Data Science course for high school students (Register et al., in press; Register, submitted; Register et al, under review; Register under review);
* The Ethical Mathematics Consciousness (EMC) Analytic and Design Framework for understanding how students' ethical and critical perspectives work together to guide their ethical reasoning and decision-making (Register et al, 2022; Register et al., submitted);
* An Ethical Decision Making in Data Science Protocol for guiding students towards critical conscious ethical decisions in data science contexts (Register et al., submitted);

Given the nature of a large DBR project, it is not feasible to document the development, modification, and findings of the overarching project in a single piece of writing. Thus, this chapter serves as an overview of the most significant products and findings of the project related to designing for ethical reasoning and decision-making in data science education. Its primary aim is to offer our process and findings as resources for those who seek to design for ethical reasoning in the mathematical disciplines. For a more detailed description of the developed constructs, frameworks, and products, please consult the corresponding articles cited throughout this writing.

The remainder of this chapter is organized as follows: First it will provide an overview of the literature related to the consequences of BDA in society which set the stage for the need for ethics in mathematics and data science education. Next it will offer an overview of the theoretical orientation that served to guide the project including our development of the instruction theory and corresponding materials for the EDS course. An overview of the DBR project will follow, including a brief description of the three pilot studies and corresponding findings that led to the development of the ERiM Principles framework, EMC Analytic and Design framework, and Ethical Decision Making in Data Science Protocol, as well as our decision to adopt a Cultural Participation Orientation for ethical data science learning environments. The chapter will culminate with a discussion of the implications for the mathematics and data science education communities related to leveraging these products and findings for the development of an ethical mathematics and data science education.

**Review of Literature**

**Consequences of Big Data in Society**

 Industry professionals and scholars concerned with the effects of data science stress the importance of developing both ethical dispositions within the field and critical data literacies for the global population (D’Ignazio et al., 2020; Ernest, 2018; O’Neil, 2016). This is not only due to its permeating influence on society, but also the documented negative effects on the well-being of individuals, social groups, and the environment. Importantly, the insights drawn from BDA can produce simultaneously positive and negative consequences for society. Case in point, in the healthcare industry, Big Data can be used to predict flu trends, pregnancy health, interactions between medications from search data, and provide insights related to the spread of infection in hospitals. However, it can also contribute to discrimination in both healthcare and insurance. For instance, fitness apps can predict how fit you are, while health scores can be developed from an individual’s purchase habits and search terms, potentially affecting health insurance rates and acceptance into healthcare programs (Martin, 2015; O’Neil, 2016).

The competing effects of BDA are further exemplified in Martin’s (2015) analysis of the ethical issues in BDA. Martin (2015) defines Big Data as an industry (as opposed to a technology) that has been criticized as a “breech of privacy, as potentially discriminatory, as distorting the power relationship and as just ‘creepy’” (p. 67). She provides a synthesis of the beneficial and questionable uses of Big Data by technology (e.g., license plate readers, facial recognition, GPS) and by context (e.g., healthcare, education, electricity, law enforcement, retail, and urban planning). Notably, each of these domains includes beneficial uses in society as well as those that are potentially harmful, and draw information from individual’s digital traces that do not require user permission. Martin’s considerations are representative of the major ethical concerns of the BDA industry that include unfair market practices, issues related to the hidden nature of algorithms, and the discriminatory effects of BDA in society, among others.

**BDA: A New Epistemology**

The negative effects of BDA are often attributed to the methodology itself. Unlike traditional research, data science identifies correlations in available data, as opposed to first developing a hypothesis and collecting sample data to fit the research question. This presents a paradigm shift for the way that research is conducted and includes epistemological differences that must be recognized and explored. For instance, core tenets of BDA include accepting messiness in data, drawing conclusions and making decisions based on correlated, rather than causal data. Furthermore, drawing insights from data requires deep knowledge of the domain and context, which the data scientists may not possess. For instance, in the social sciences, BDA provides tools for analyzing large amounts of rich sociopolitical data. However, the predominantly privileged demographic of data scientists today implies a “skill deficit for analyzing and making sense of such data” (Kitchin, 2014, p. 10). Importantly, large and available data sets are grounded in significant social, historical, and cultural contexts, that when not considered, can reinforce biases and result in significantly negative effects for non-dominant groups in society (Kitchin, 2014, p. 10).

An additional concern related to BDA is its influence in politics and policy. In the last few decades, there has been an increased interest in evidence-based policy making that capitalizes on society’s trust in quantitative procedures and representations (Reider et al., 2016). They argue that maintaining a social order is dependent upon society’s trust in the system and that the ongoing “computerization of society” increasingly feeds people’s “trust in numbers” (Reider et al., 2016 p. 1-3). Citing boyd and Crawford (2012), they argue that

Big Data is not just about technological progress, but about a “widespread belief that large data sets offer a higher form of intelligence and knowledge that can generate insights that were previously impossible” (Rieder et al., 2016, p. 3).

While BDA certainly offers new options for gaining data-based insights, the authors remind us of our tendency as a society to view data as “raw, objective, and neutral--the stuff of truth itself” despite the fact that both data, and notions of trust are historically and contextually situated (Reider et al., 2016, p. 3). Furthermore, they argue that by placing our societal trust in BDA, policy makers can avoid making difficult and critically informed decisions. Instead, they can rationalize unpopular or discriminatory decisions using “the numbers” as a scapegoat (Reider et al., 2016). Importantly, scholars interested in the ethics of Big Data reject notions of data and other digital goods as neutral and objective, but rather as entities which are shaped by and have consequences for society (Dourish et al., 2011) that include but are not limited to market effects, a lack of transparency and ability to critique models, and discrimination, as described in the following sections.

**Market Effects**

Scholars have elaborated on the interactions between privacy and Big Data as it relates to the current neoliberal market. According to Zuboff (2015, 2019) BDA has leveraged what she terms *surveillance* or *information capitalism* to transform the neoliberal idea of an *unknowable* market into a *knowable* one. That is, using BDA techniques, corporations are able to observe and analyze trends in the market by capturing users’ behaviors and characteristics. Since those who can afford to transform data into information are more likely to succeed financially (Zuboff, 2015, 2019), it has been suggested that those who possess the capital to employ BDA (typically large and/or global organizations) have a significant advantage over those who do not (small businesses). In addition, the market effects of BDA influence the transfer of wealth among world citizens (Zarsky, 2016) and have been found to disenfranchise already marginalized populations, contributing to a greater financial divide between distinct social groups (O’Neil, 2016; Zarsky, 2016).

**Algorithms: The Black Box**

The use of algorithms has been further critiqued as a primary decision making tool in society (Crawford, 2016; Gillespie, 2013; Zarsky, 2016). Algorithms are mathematical models intended to describe and make predictions about phenomena and are used to make the “best” decision based on a statistical analysis of the data (Zarsky, 2016). They are typically embedded in software and coded in a language unfamiliar to the average citizen (i.e., the black box) making them difficult to critique. Data scientists typically chose the model which performs best on both the train and test subsets of historical data. But what if the training data includes historical bias or is discriminatory towards certain groups? If not properly dealt with, algorithms typically adopt biases from the training data, catalyzing questions of their validity and reliability in decision making processes that affect the well-being of individuals and groups in society (Zarsky, 2016). In addition, people who have similar characteristics may receive different opportunities or treatment based on their digital traces (which do not require permission to obtain), speaking to issues of fairness and discrimination (Zarsky, 2016). Resulting from the black box nature of algorithms, those who are managed most often by technology are neither able to critique, nor challenge the models which may unfairly govern their lives (Noble, 2018; O’Neil, 2016).

**Discrimination and the Privilege Hazard**

The discriminatory effects of Big Data are arguably the most concerning implication of the widespread reliance on BDA, as argued by industry professionals and researchers. Specifically, training algorithms on historically biased data often reinforces social stereotypes and/or places individuals and populations in a recurring cycle of misclassification (i.e., feedback loop) (O’Neil, 2016). Since algorithms use historical data to make predictions, non-dominant groups who have been targeted and identified as demonstrating undesirable behaviors by dominant members in society may become confined to a vicious cycle of self-fulfilling prophecy based on demographics such as race, gender, address, credit score, etc (Benjamin, 2019; D’Ignazio et al., 2020; Eubanks, 2019; O’Neil, 2016).

Contributing to this issue is the dominant demographic of data scientists in the field. In their text, *Data Feminism*, D’Ignazio and Klein (2020) highlight how the prevailing white and/or male and/or upper income demographic of data analysts and professional mathematicians exacerbates the often marginalizing effects of their products. They define the *privilege hazard* that occurs when teams of data scientists are composed of people primarily from dominant groups in privileged positions. Although often unintentional, designs created in these contexts reflect the dominant perspectives, experiences and values of the privileged creators at the expense of nondominant identities and viewpoints (D’Ignazio et al., 2020; Noble, 2018). Having limited or no experience with social and/or financial struggle or the lived-experiences of the masses, privileged data scientists are often ill-equipped to identify oppressive situations in the world resulting in a lack of consideration for the impact of their models on societal groups (D’Ignazio et al., 2020). Consequently, one of the biggest threats to society that has come from globalization is the hard coding of discrimination in the processes that are increasingly used by world governing entities (D’Ignazio et al., 2020).

**The Need for Ethics in Data Science Education**

To combat the aforementioned detrimental effects of BDA, scholars argue for the adoption of a sociopolitical perspective within the Data Science industry. Analogous to this stance*,* third-wave-feminist Nel Noddings (1988) argues for a revival of ethics as a primary aim for modern schooling. In contrast to notions of institutionalized education as a means for the development of academic skills only, Noddings (1988) urges that schooling in the U.S. has always been concerned with the development of righteous citizens. However, mid-century notions of righteousness stemmed from dominant Christian, Aristotlean, and Kantian ideals concerned with rights, needs, and individualism; values that were also essential for encouraging Christian charity, American entrepreneurship, and ultimately, capitalism (Noddings, 1988). Given that the U.S. population consists of individuals and social groups whose ethical perspectives differ from these ideals, our ethical goals for public education must be adapted to accommodate the needs, values, and belief systems of those beyond the dominant group.

With regard to data science education, Rubel and colleagues (2021) stress the relevance of power in relation to data, arguing that power and responsibility may be hidden when people interact with technology if they lack an awareness of how mathematics operates within the software and/or how the outcomes influence society, while Register, Stephan and colleagues argue that ethics should be an explicit design focus of any data science educational materials (Stephan et al., 2021; Register et al., 2021). To initiate this shift in mathematics and data science education, Register and colleagues embarked on a 4 year (and counting) Design Based Research (DBR) study to 1) understand how students reason ethically in data science contexts, and 2) develop instructional theory and materials for an Ethical Data Science course (Andersson et al., 2022; Stephan et al., 2020; Register et al., 2021; Register, under review). An overview of the project will be described in the Research Approach section of the paper. For now, it is important to understand that DBR is an educational research approach used in situations where educational theory and corresponding empirical studies are either missing or in need of reform, such as ethical mathematics and data science education. Since neither of these domains are empirically well-defined, the theoretical orientation for this work was developed iteratively, over the course of the project, with the intent to support not only ethical reasoning in the mathematical disciplines, but also to support students’ positive ethical and data science identity development. The next section will provide insight into our process of defining our theoretical orientation, followed by the specifics of our DBR approach, and the products of our work which are conjectured to support the mathematics and data science education community in designing for ethical data science learning.

**Theoretical Orientation**

The theoretical orientation that guides this dissertation draws on literature in feminist ethics (Noddings, 1988; Levinas, 1969, 1997: Puka, 2005), ethical mathematics education (Atweh, 2013; D’Ambrosio, 1998; Ernest, 2018a,b), Freire’s Emancipatory Education, and Critical Mathematics Education (CME) (Frankenstein, 1983, Gutstein, 2005; Skovsmose, 1994), and Cobb and Hodge’s (2019) Cultural Participation Orientation toward learning. The following sections will describe how we drew on each of these domains to develop a comprehensive theoretical orientation for our work.

**Ethics as the Foundation for Mathematizing**

Theorists in mathematics education contend that our relationship with mathematics may be marked by ethical responsibility (Boylan, 2016; Neyland, 2004). Such scholars view mathematics as undeniably integrated into the technical, political, industrial, military, social, etc., facets of the Westernized world (D’Ambrosio, 1998; Lengnink, 2005) often “unconsciously influencing our human thinking and acting” and requiring the development of mathematical literacy which extends beyond content (Lengnink, 2005, p. 246). Scholars who have attempted to apply ethical frameworks to mathematics education typically draw from relational (Levinas, 1969, 1997) and feminist ethics (Noddings, 1986; Puka, 2005). The key conjecture of relational ethics is that to be human is to be in relationships *with* and *for* the other without a demand for reciprocity and mutual obligation (Atweh, 2001). Upholding this perspective, mathematics education scholar Paul Ernest (2013) argues that our knowledge, and therefore research, rests on trust in the ethical accumulation of information and that as social creatures, our survival depends on our ethical and cooperative behavior with one another (Ernest, 2013). It is his view that ethics must serve as the foundation for mathematizing and philosophizing, noting that “ethics arises from the ways in which persons live together and treat each other” (p. 9). While this reasoning resonates with our purpose, a key question when designing for students’ ethical reasoning arises: What *kind* of ethic do our students need?

Unfortunately, there is a dearth of *empirical* work related to promoting an ethical mathematics education, while the literature on ethical reasoning in mathematics education is fragmented in the sense that ethics and social justice are often discussed separately. With that being said, Atweh and colleagues (2009) argue that ethics and social justice are considered separate but interdependent realms since issues of social justice are typically concerned with the social activity of groups of people and the fair enjoyment of social benefits, while issues of relational ethics are concerned with our interactions. Specifically, ethical considerations are based upon people’s moral responsibility to one another, establishing “social justice concerns as a moral obligation, rather than charity, good will or convenient politics” (Atweh et al., 2009, p. 268). Therefore, we take the position that “ethics in mathematics education both supports, and lays the foundation for, concerns about social justice” (Atweh et al., 2009, p. 268). As such, we drew on literature in Critical Mathematics Education as a starting point for conceptualizing what we mean by an Ethical Mathematics Education.

**Drawing from Critical Mathematics Education (CME)**

CME scholars argue for a contextualized mathematics curriculum which is based on students' realities (whether at the micro or macro level) for the purposes of developing a critical consciousness of, and empowerment to dismantle, the oppressive forces in one’s life. Importantly, CME adopts Freire’s position that a liberatory education can only be executed through praxis. In Freire’s view, praxis is composed of critical reflection and practical action which can only be achieved through discourse. As such, CME classrooms are dialogue and discourse centered. They reject traditional “banking” teaching methods in which teachers “deposit” information into the heads of quiet and submissive students (Freire, 1970/2018). Rather students and teachers are positioned as co-learners who together, decompose and reflect on the chosen phenomenon using mathematics, and in some cases, use their newfound understanding to become agents of change (Gustein, 2005, 2016). In ideal cases, explored phenomena are identified through generative themes, in which students determine the topics of inquiry based on their experiences, communities, and global phenomena (e.g., Frankenstein, 1983; Gutstein, 2016).

While the tenets of CME respond well to guidance offered by scholars for developing students’ ethical reasoning more generally (Noddings, 1988), Boylan (2016) suggests that there is a lack of discourse related to consideration of the *other* as an ethical imperative for mathematics. In particular, Critical Mathematics pedagogies typically focus on liberation of the self or that person’s social group from past or current injustices, through the development of critical praxis (Freire, 1970/2018). Such studies are more often done in the context of racially and/or ethnically homogenous and historically marginalized populations of students who explore social justice issues relevant to their community through mathematics (Berry, 2004; Gutstein, 2005; Rubel et al., 2016; Rubel, 2017). Few studies concerned with teaching for social justice have done so in the context of heterogeneous and/or privileged groups of students, with notable exceptions by Kokka (2020) and Esmonde (2014), while none (that we could find) center ethical designs for the future. However, as Skovsmose (2016) argues, teaching for social justice without including students of privilege or heterogeneous populations of students, might miss the pedagogical and ethical consideration of the *other* and overlook a critical opportunity for the actual development of justice in society. Although such students may not be subject to certain types of social oppression, and may actually benefit from the social and economic inequalities that are studied in CME, their engagement in “reading and writing the world with mathematics” might help them to develop “radical new perspectives” that support their participation in developing a just world (Skovsmose, 2016, p. 3).

As a start, Atweh proposes a *Socially Response-able Mathematics Education* whose primary role is to “equip students with knowledge, skills and dispositions to respond to the demands of their current and future lives” (Atweh, 2001, p. 6). They argue that the foremost concern in ethics is our relationship with and for others, therefore *ethics actually serves as the foundation for concerns of social justice* (Atweh et al., 2009). Importantly, this is true only from the perspective of *relational* ethics, as other major *normative* theories that characterize the ethics of decision making neither show a concern for relations nor justice. For instance, the foremost concern of:

* *consequentialists* is the outcome of the decision,
* *deontologists* is the moral intent of decision or actor, and
* *virtue ethicists* are patterns in behavior over time.

Translating this to the data science industry, scholars argue that traditional normative ethical frameworks are insufficient for protecting against the repercussions of BDA due to the fields’ typical lack of attention to its sociopolitical elements (D’Ignazio et al., 2020). Therefore, we cannot simply argue that students need to learn to be ethical in a general sense since our ethics are a product of our culture, communities, experiences, etc. which are naturally diverse and often competing (Brown University, 2013). Rather, we must champion ethical perspectives (like Atweh and colleagues) that lend themselves to empathy, justice, and sociopolitical thought.

**Feminist Ethic of Care and Social Responsibility**

Both Ernest (2013) and Atweh (2001) argue for an ethics of mathematics that acknowledges its social responsibility and implications for freedom, justice, trust, and fellowship (Noddings, 1988; Puka, 2005). Drawn from these arguments, the central ethical perspective taken in this study is that of *feminist ethics*, or more specifically, an e*thic of care* (Noddings, 1988) and *social response-ability* (Atweh et al., 2009; Puka, 2005). This is in contrast to traditional normative ethical systems that prioritize consequences, duty, and/or virtue as the basis of their ethical decisions.

As argued in this work, feminist notions of an *ethic of care* and *social response-ability* are at the center of developing socially responsible world citizens concerned with relations between the self and others, because *together*, they have the potential to encourage critically conscious ethical decision making through interpersonal empathy and a sense of responsibility to others. To clarify, a feminist *ethic of care* speaks to the students’ interpersonal empathy and is characterized by a desire to care for others based on positive experiences of being cared for when making ethical decisions (Noddings, 1988). In contrast, *social response-ability* refers to a higher level of empathy tied to the system. It is the ability to respond to the demands of our own ethical well-being while responding to the demands of others through the promotion of justice and critique of power structures (Atweh, 2009; Puka, 2005). Together, an ethic of care and social response-ability prioritize both interpersonal and systemic empathy and sociopolitical thought, driving their explicit consideration of context, identity, experience, and power (Noddings, 1988; Puka, 2005). We prioritize this ethical perspective due to the nature of the data science industry having significant implications for diverse individuals and social groups in society, and because we are designing for high school students in U.S. public schools. This is not to say that a feminist ethical perspective is appropriate for all contexts. However, when training students to be ethical with respect to their role as a future data scientist and global citizen, we argue that feminist notions of ethics are most appropriate. Furthermore, these perspectives offer an extension to programs that explore past or current oppressions by examining one's current data science activities ethically in order to prevent *future* injustices.

As a final argument for prioritizing feminist ethics, we no longer live in bounded communities (if we ever did), where we can afford to make decisions that have an impact only on like minded people. Instead, globalization and the increased use of BDA allow policy makers to make decisions that scale to many diverse populations with multiple, often conflicting, perspectives and needs. Unlike other normative perspectives, individuals who hold a feminist ethic of care and social response-ability typically hold a *pluralist* moral disposition characterized by their open-mindedness and ability to recognize that there are often multiple contrasting perspectives, which are all legitimate, in a given context (Norlock, 2019; Pateman, 1988). Even in situations where ethical acts are determined by a social contract between citizens, feminists reject the notion that ethical actors have equal access to the contract itself , especially for those who sit on the margins of society (Mills, 1997; Pateman, 1988). As such, we see moral pluralism as *necessary* for critically conscious ethical decision-making in data science, since the decisions made through data science impact individuals from different cultural backgrounds, with diverse needs, experiences, desires, and epistemologies.

In the following section, the aforementioned considerations are synthesized into what serves as the guiding framework developing students’ ethical reasoning in mathematics and data science contexts. I will then present the orientation for learning (Cultural Participation Orientation, Hodge et al., 2019) that we adopted in order to support students' development of ethical mathematics consciousness while honoring their diverse and intersecting identities.

**Ethical Mathematics Consciousness (EMC)**

At the time of this study, a framework for designing for and analyzing students’ ethical reasoning with regard to these disciplines did not exist. With that being said, frameworks for interpreting students’ critical consciousness (Diemer et al., 2015) and critical mathematics consciousness (Kokka, 2020; Stephan et al., 2020) have been developed to identify characteristics of students’ reasoning related to the oppression of marginalized groups and their willingness to act on such instances of oppression. Developing an ethical disposition however, requires robust sociopolitical understandings as well as knowledge of the structures and mechanisms which contribute to social injustices, including mathematical processes, products, and ways of knowing. In other words, it requires a *critical consciousness* of the ways in which mathematics and mathematical processes serve to disenfranchise some, privilege others (Stephan et al., 2020). In addition, an ethical disposition requires looking beyond sociopolitical issues to those that pose an ecological threat, that is, a threat to environmental systems, animals, human systems, and/or threats towards humans that are not specific to marginalized groups or individuals (Boylan, 2016).

Recall that a primary goal of this work is the development of students’ *ethical mathematics consciousness* (EMC) (Andersson et al., 2022; Stephan et al., 2020; Register et al., 2021; Register, under review). Derived from Freire’s conception of *critical consciousness*, Kokka (2020) defines critical mathematics consciousness (CMC) as the development of sociopolitical understanding, critical civic empathy, and action taking through mathematics. The definition for EMC used in this research differs in that it attempts to tie students’ critical consciousness to their forms of ethical reasoning, transcends past or current sociopolitical injustices to include environmental and ecological concerns, and focuses on ethical designs and accountability for the future. Specifically, *EMC* refers to the *awareness that human beings do mathematics; thus, there are potential ethical dilemmas and implications of mathematical work which may affect entities at the individual, group, societal, and/or environmental level.* It includes *sociopolitical, ecological, and communicative mathematical awarenesses, and a willingness and commitment to act* (i.e., *ethical mathematics agency)* (Andersson et al., 2022; Stephan et al., 2020; Register et al., 2021; Register, under review)*.* The three interconnected awarenesses are defined as follows:

* *Sociopolitical mathematics awareness*: that mathematics is used to model and interpret the real world and can be used to make decisions (both at the individual and systemic levels) that may further disenfranchise (or liberate) marginalized groups.
* *Ecological mathematics awareness:* that mathematics has been socially constructed by human beings and thus has implications for humans, animals, the environment, and its interconnected ecologies.
* *Communicative mathematics awareness:* that mathematical communication has the power to educate and mis-educate society and encourage the masses to act in certain ways.

Importantly, EMC exists on a continuum of both ethical and critical thought which guide and inform one another. The *ethical components* of EMC include the actor’s demonstrated ethical and moral perspectives, their unit of analysis when the agent makes the decision, and the stakeholders and goals of their ethical decisions, while the *critical components* include critical sociopolitical/ecological thought related to the oppression of individuals, entities, or ecologies, the cause of the oppressive situation, and their sense of empowerment and personal agency to dismantle the given oppressive system (Register et al., under review). In the following section, I describe the development of the EMC Framework used to guide our design process and analysis of students’ ethical reasoning in the EDS course, beginning with the pilot study findings that directed our path.

# Research Approach

## Overview of Pilot Studies

This study employed a Design Based Research approach to designing for ethical mathematics consciousness (Cobb et al., 2003). The pilot phase began in Fall of 2019 and included 3 task-based interview series intended to characterize students' ethical reasoning in data based contexts (Andersson et al., 2022; Reinke et al., 2022; Register et al., 2021; Stephan et al., 2020). The first pilot study was conducted in Spring of 2020 with 15 middle and high school students from 2 U.S. schools of choice. The participants ranged from 8th to 10th grade, diversely gendered mathematics students assigned to 8th grade Math 1, freshman Standard Math 1, Foundations of Math 1, or Honors Math 2, who are considered educationally and/or socioeconomically privileged. Three participants classified themselves as African American, one as Asian American, and the remaining 11 as White. The purpose of this pilot phase was to develop a baseline and identify characteristics of relatively privileged students' ethical reasoning in data science contexts. They were asked to respond to 5 task-based interview questions that positioned them as decision makers either in the data science industry role, or as a citizen responding to publicized data based visualizations in the media. Contexts included analyzing statements made about racial disproportionality the victims of police shootings, contrasting statements from health and financial organizations related to entering back into society amidst the COVID-19 surge of 2020, determining whether to sell data about youth tobacco use and to whom, and deciding whether to sell facial recognition software to the police, among others (See Register et al., 2021 and Stephan et al., 2020 for detailed methods and findings).

The second pilot study occurred in the Fall of 2020 in a 7th grade classroom, also in a U.S. school of choice, where we designed a 2 week lesson sequence on ratios and proportions in the context of teen vaping. Prior to the lesson, 10 socioeconomically and educationally privileged, volunteer student participants, were given the same ethics interviews as the first pilot study (Reinke et al., 2022).

The third pilot was conducted in Fall of 2021 with 11 preservice mathematics teachers from the US and Sweden (SWE). The purpose of this pilot was slightly different in that here, we attempted to understand how training teachers reasoned ethically in order to understand the nuances in ethical reasoning among mathematics teachers and learners. Six new interview tasks were developed to align with the conjectured mathematical proficiencies of undergraduate preservice mathematics teachers. Contexts included analyzing media statements made about the effectiveness of COVID-19 vaccines, disproportionate prison rates by race/ethnicity in the US and immigration status in SWE, targeted marketing practices, targeted policing, and facial recognition software for police use (See: Andersson et al., 2022 for detailed methods and findings).

Our analysis of the pilot interviews resulted in the following significant findings that directed the development of the ERiM Principles Framework, the EMC Analytic and Design Framework, and the adoption of a Cultural Participation Orientation towards learning for the purpose of developing EMC. The findings are offered below, followed by a discussion of how we responded to these findings.

1. Design heuristics in mathematics education must be expanded to consider issues beyond the technical components of mathematics.
2. Critical and ethical frameworks for mathematics education must consider the diverse forms of ethical reasoning that exist both within and across cultures (i.e. We can’t just say “people need to be ethical!” Ethical according to what perspective?) (Register et al., 2022).
3. Grounding the mathematics instruction in ethical and critical contexts requires that the designers consider the potential implications of immersing students in controversial scenarios (Reinke et al., 2022, Register et al., 2022).

## Response to Pilot Study Findings

* ***Finding 1: Design heuristics in mathematics education must be expanded to consider issues beyond the technical components of mathematics.***
* ***Response: The Ethical Reasoning in Mathematics (ERiM) Principles framework***

The Ethical Reasoning in Mathematics (ERiM) Principles framework (Table 1) was developed to guide the creation of ethical tasks and activities in mathematics and data science. In particular, its purpose is to offer a range of ethical issues that may be leveraged as contexts for such tasks. Its development is described by Stephan et al. (2020) in their analysis of select tasks from the first pilot interview study. For the sake of brevity, it is not described in this chapter. However, the impact of the ERiM framework lies in its utility as a guide for the creation of exploratory tasks that consider real world consequences of mathematical and data science decisions in society. That is, within an ethical task, students may draw on any number of these principles to understand the ethical issue and/or justify a given solution to an ethical issue as described in Register et al. (under review). In sum, it offers common industry-specific ethical considerations that can be leveraged in ethical mathematics and data science education.

**Table 1. Ethical Reasoning in Mathematics Principles**

|  |  |
| --- | --- |
| **Ethical Principles** | **Considerations** |
| Privacy | How does respect for freedom or personal autonomy apply? Is confidentiality required? Is consent needed or obtained? Is privacy violated? |
| Fairness (equality) | What is the fair or just thing to do? Is there fair access to systems that are created? |
| Accuracy | Is data reliable and accurate? |
| Accountability | Who is accountable? Have they communicated the data in a misleading manner? Is the source reliable? |
| Property | Whose data is it to sell? Who owns the data? |
| Loyalty | Is the decision/activity loyal to the organization (e.g., makes profit, keeps ideas within organization, does not use organization’s ideas to make money elsewhere) |
| Accessibility | What information does an organization have the right to access about people? Who has access to this data? User buyer? |
| Algorithm Bias | Are algorithms objective? Do algorithms (un)knowingly discriminate against individuals or groups? |
| Transparency | Are the codes for algorithms readily available for inspection? |
| Ecological | Has the impact on humans and ecosystems been considered? |
| Employment | Will the decision/activity harm an individual’s or group’s employment status? |
| Discrimination | Has the decision/activity avoided negative effects on oppressed societal groups? |

Sources**:** Stephan et al., (2021); Register et al., (2021)

* **Finding 2: *Critical and ethical frameworks for mathematics education must consider the diverse forms of ethical reasoning that exist both within and across cultures***

## Response: *EMC Analytic and Design Framework*

While there is much to draw from the literature about teaching for critical consciousness in classrooms composed primarily of underrepresented or oppressed groups (e.g. Berry 2004; Gutstein, 2006; Rubel et al., 2016), it is essentially undefined when working with students with greater privilege. Therefore, in our attempts to foster critical consciousness in more privileged students, the following notions drove us to explore how individuals make ethical decisions in data science contexts, shedding light on the diverse forms of ethical reasoning that may exist within and across classrooms more generally.

1. Students’ decision making is driven by their normative ethical perspective, mid-level ethical principles (social norms), and role specific obligations (Diekmann, 2011; Keefer & Ashley, 2011).
2. Students hold a diversity of ethical perspectives based on their background and experiences that may or may not include concern for positive relations or justice (Stanford, n.d.; Brown University, 2013).
3. Certain ethical perspectives lend themselves better to concerns for equity, positive relations, and social justice (Noddings, 1988; Norlock, 2019).
4. Students of privilege may not have experience considering issues of social justice (Skovsmose, 2016).

The EMC Analytic and Design framework (illustrated in Table 2) is a product of our research into existing normative ethical theories and their relationship with critical consciousness. It was designed to understand how students' ethical perspectives may align with their demonstrated critical consciousness (Table 3) in mathematical contexts that require ethical decisions in order to inform the design of ethical mathematics and data science curriculum materials.

With regard to its utility, the EMC Analytic Framework (Table 2) serves as both an analytic tool for interpreting students’ ethical and critical reasoning and as a tool to design instruction. As an analytic tool, the EMC Framework can help us identify the forms of ethical reasoning that high school students exhibit and how that may change over time and through instruction. As a design aid, this tool helps the designer identify diverse ethical perspectives and make conjectures about potential instructional problems that can challenge problematic viewpoints, motivating students to develop a pluralist feminist ethic. For instance, we anticipate that students who grew up in the U.S. may subscribe mostly to deontological ethical systems associated with Natural Law Theory (the foundation of the U.S. constitution) or Divine-Command Theory (morality based on religious views). If the majority of students start here, then the design challenge involves identifying the characteristics of instructional problems that encourage these students to make ethical considerations beyond such theories, to promote an ethic of care and social response-ability

# EMC Framework Development

In developing the EMC Analytic and Design Framework (Table 2), a literature review of normative ethical theories was conducted to differentiate between the characteristics of each ethical system and how they relate to each level of critical consciousness. The alignment of ethical, moral, and critical perspectives was conducted based on whether the demonstrated

**Table 2**

*Ethical Mathematics Consciousness (EMC) Analytic and Design Framework, (Register et al., 2023)*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|

|  |  |
| --- | --- |
| **Characteristics of Actor’s Ethical Reasoning** | **Characteristics of Actor’s Critical Reasoning** |
| **Ethical Perspective** | **Moral Disposition** | Unit of Analysis | Ethical Stakeholders | Ethical Goals | Critical Sociopolitical/ Ecological Thought | Perceived Causes | Agency + Empowerment | ***Critical Mathematical* Consciousness** |
| **Feminist Ethics***(Ethic of Care & Social Response-ability)* | Pluralistic, transnational, non-ideal | Relations, Context | Self + Others | Dismantle oppressive systems + preserve relations | Yes | Systems/ dominant group | Empowered to act by focusing on *system* | Critical transitivity***Actualized EMC*** |
| Contractarianism*(Social Contract, Rawl’s Theory)*Edumonaism *(Virtue Ethics)* | Pluralist, Relativist,  | Consequences, Agent, and/or Act/Intent | Self, Others | Equity,  |  | Systems/ dominant group | Put faith in others to act | Systemic Semi-Transitive |
| Yes | Isolated incidents  | Empowered to act on isolated injustices | Isolated Semi-transitive |
|  | Dominant group or individual | Disempowered to act | Disempowered |
| Utilitarianism*(Greatest Good)*Deontology*(Duty Ethics)*Edumonaism *(Virtue Ethics)*Egoism*(Self Preservation)* | Relativist, Absolutist | Consequences,Agent, Act/Intent | Others,Self | Equality,Duty, Virtue, Self- Preservation | No | Fault of oppressed,*Technology/ media influence* | Onus on oppressed to act | DysconsciousMassified Consciousness |
| God/Luck | Disempowered to act | Intransitive |

 |

Table 3. EMC Levels of Consciousness

|  |  |
| --- | --- |
| ***Level of Consciousness*** | **Characteristics of Individual's Ethical Reasoning** |
| Critical transitivity | * Exhibits critical thought and concern for justice
* Recognizes systemic influences on the injustice
* Seeks to dismantle oppressive systems.
 |
| Semi-transitivity(isolated)(systemic)  | * Exhibits critical thought
* May see the systemic cause of the oppression, but does not attack it at its root.
* May perceive and attack the cause as isolated or local incidents (*isolated semi-transitive*) or put their faith in other, more powerful individuals or groups to change oppressive situations (*systemic semi-transitive*).
 |
| Disempowered | * Exhibits some critical thought
* Disempowered to act because they do not feel that they have the ability to overcome those in power.
 |
| Dysconscious | * Minimal (or no) critical thought, due to a “distorted vision of oppression” (King, 1991, p. 3).
* May “justify inequity as the natural order of the world,” think that the oppressed are at fault for their current situation, and place the onus of responsibility to overcome the injustice in their hands (King, 1991, p.3).
* May be taught through familial and educational influences, or by media effects (i.e., massified consciousness) (King 1991, p. 3).
 |
| Intransitive | * Does not exhibit critical thought, perceiving their oppressive situation as a consequence of God’s will or bad luck.
* Disempowered to act (i.e. agency is irrelevant as only a shift of luck or divine intervention are the only means to dismantle the injustice).
 |

ethical system allows for the following considerations (see Appendix A for an overview of normative ethical perspectives):

* Does the ethical system allow for critical sociopolitical/ecological thought?
* What is their unit of analysis? Are they concerned with the morality of the actor? The intent or consequences of the act? Or relations in context?
* Who are the stakeholders of the ethical system under consideration? That is, are they concerned for the ethical well-being of the self, others, or the self and others (note that *critical consciousness* requires both).
* Are the ethical goals intended to improve/preserve life for all equally? Equitably? Or do they intend to preserve relations and dismantle oppressive systems?

EMC therefore exists on a continuum of *both* ethical and critical thought which guide and inform one another. The *critical elements* (right side of Table 2)emulate Freire’s work and include evidence of critical thought related to the oppression of individuals, entities, or ecologies, the cause of the oppressive situation, and their sense of empowerment and personal agency to dismantle the given oppressive system (Register et al., 2023). Within a given context, individuals may demonstrate one of the following six levels of consciousness: *critically transitive, systemic semi-transitive, isolated semi-transitive, disempowered, dysconscious*, or *intransitive* (see Table 2). Drawing from Freire, Shor (1993) defines *critical transitivity* as the actualization of full critical consciousness where the individual engages in critical reflection, recognizes the systemic influence on oppression, and is *empowered to act* by attacking the causes of oppression *at the systems level*. Freirean theory maintains this as the goal of a liberatory education.

When framing the *ethical elements* of EMC (left side of Table 2), we drew on the *normative* ethical perspectives that middle, high school, and college students of privilege demonstrated in our pilot studies. The *ethical elements* of EMC include:

1. the actor’s demonstrated normative ethical perspectives (the systems that guide their decision making processes),
2. their unit of analysis when the agent makes the decision,
3. the stakeholders of the decision,
4. and goals of their ethical decision.

The *ethical components* typically correspond with the *critical components*, in that a person’s ethical perspective frames their sociopolitical thought, dictating their level of concern for oppressed entities and the promotion of justice. For instance, individuals who demonstrate a feminist ethic of care and social responsibility are more likely to reach critical transitivity due to their explicit attention to identity, relations, context, power, and justice. In contrast, individuals who demonstrate a solely *consequentialist* ethical perspective (e.g. utilitarians and egoists), respectively prioritize the greatest benefit for the greatest number, or self-preservation for the actor. Such individuals are typically moral absolutists (utilitarians, egoists) who rarely consider issues of power, context, interpersonal relations, or access in their ethical reasoning. Rather their main concern is the consequence of the act in terms of the *greatest* good (supporting dominant ideologies). As such, they are less likely to demonstrate the *critical components* of EMC.

In contrast, a feminist ethic of care (Nodding, 1983) and a feminist ethic of social reasponse-ability (Puka, 2005) map to higher levels of critical consciousness (Table 3) within the EMC Framework (Table 2) because *together*, they explicitly promote critical consciousness. That is, together, an ethic of care and social response-ability prioritize both interpersonal and systemic empathy and sociopolitical thought, driving their explicit consideration of context, identity, experience, and power (Noddings, 1988; Puka, 2005). As a final note, a pupil's EMC classification is context dependent in that it draws on their ethical reasoning within a specific situation, not their ethical disposition as a whole. That is, a student may reason mostly from a consequentialist perspective in one context, but a feminist perspective in another.

## Demonstrating Our Use of the EMC Framework

 To exemplify how the EMC framework was used, the FaceRec task, designed for the third pilot study is offered in Figure 1. Note that the task purpose in terms of EMC as well as the potential ERiM considerations that could be made while responding to this task are offered on the left side of the figure. In Figure 2 that follows, excerpts from two interview participants from the EDS course are contrasted according to how their reasoning within the FaceRec task would be classified according to the EMC framework.

Within the FaceRec context, Sam (classified as disempowered) demonstrates a fairly non-critical consequentialist perspective towards understanding the issue. That is, he suggests that the primary issue at stake when using facial recognition to classify criminals is the potential time wasted and loss of income by misidentifying a perpetrator. In contrast, Moksh (critically transitive) characterizes the issue as a systemic one that has the potential to confine members of marginalized communities (Black males in the U.S.) to a feedback loop which contributes to the incarceration cycle in U.S. prisons and a lack of social mobility. Moksh further demonstrates a critical perspective when reasoning through his decision to recommend an established software stating that

The main thing is--would you rather have a lower darker male percentage, and a higher, lighter female percentage? Or have a higher, darker male percentage and a little bit less lighter female percentage? [...] Considering today's society, I would rather have my police department recognize darker males with more accuracy. Otherwise, I'm just creating those, those loops where more people get incarcerated for like, uh, invalid reasons.

Moksh’s critical reasoning translates directly into his proposed solution where he offers a piecewise solution that attempts to address the issue from several perspectives. That is, he tackles the issue from a technical standpoint stating that he would “train the algorithm on more faces”, potentially increasing the algorithm's ability to accurately detect darker and female faces. He further addresses accuracy by recommending that “the police department have more than just one data engineer [...] and have kind of like a team to, to feed more data into this software to improve its accuracy hopefully, and, and just, and just make sure that the software can, can detect to its best potential.This recommendation arguably addresses the privilege hazard by expanding the data science team. Finally, he attempts to add safeguards by informing the police department that the software is “not 100% accurate and they should use other evidence to make sure it's the right person.” That is, to use the facial recognition software as a secondary identification method, not the sole piece of evidence when arresting a perpetrator. In contrast, Sam’s solution did not include evidence of critical reasoning. Rather, when asked what he could do as the data science engineer to reduce harm, he stated that we should “wait a few years for the technology to improve” indicating not only a lack of critical thought, but a lack of agency as well. As a result of their demonstrated reasoning, Moksh was classified as demonstrating Critical Transitivity in this task, while Sam was classified as Disempowered.

With regard to how we modified our instruction to promote reasoning like Moksh’s when making ethical decisions, we analyzed how and why students like Sam may not have reached higher levels of EMC after the EDS course (See: Register et al., under review). Key findings of this analysis include that differences in the characteristics of students’ ethical decisions may be explained by their ability to consider diverse perspectives in their reasoning, the forms of

**Figure 1**

*Example Interview Task: FaceRec*

**Figure 2**

*Example use of EMC Framework for the FaceRec Task*

relevant knowledge they hold, and the role that they are afforded in the context. In particular, we found that:

1. Pluralism in ethical perspectives, knowledge of the data science industry and its methods (DSK), and their sociopolitical knowledge (SPK) influenced students’ ability to identify an ethical issue.
2. DSK influenced students' ability to develop a solution to the ethical issue.
3. The role of the student within the tasks influenced their decision to act upon a particular solution.

In particular, students who demonstrated high levels of agency, typically drew on multiple ethical perspectives that included several mid-level ethical principles and moral theories, and in some cases, their role specific obligations within the context. Importantly, this does not necessarily imply that these students hold these ethical perspectives (i.e. concern for consequences or intent does not mean that students prescribe to a solely consequentialist or deontic ethical perspective), but rather indicates that they are considering those perspectives as valid in their reasoning. In our experience, students who are able to consider more perspectives, typically develop solutions and/or make decisions that have a wider positive impact because they attempt to understand and resolve the issue by tackling it from multiple angles.

It was also found that students’ relevant knowledge dictated how they identified the issue, and the characteristics of the solution that they could propose as a result. Significantly, students’ mathematical knowledge (MK), SPK, and DSK, played a role in their identification of the issue. For instance, in the FaceRec task, students first used their MK to understand the differences in accuracy of the facial recognition software and the prevalence of crime by location. Then most of the students drew on their SPK related to the mass incarceration of people of color in U.S. prisons and connected that to their DSK related to feedback loops in BDA. With that being said, it was also found that students’ DSK (or lack thereof), seemed to impact the solutions they were able to develop. That is, high DSK enabled students to create solutions that were industry specific and feasible (e.g. Moksh in FaceRec), while students with low DSK were less likely to do so.

Finally, we recognized that the role of the student in the given context impacted the solution that the student chose to enact. For instance, several students pondered the impact of making an idealistic (ethical) decision versus a practical (profit-based) solution on their continued role in the company, potentially losing clout as a decision maker if they chose a solution that reduces profit. In other cases, students discussed their ability to enact the solution itself. For instance, in FaceRec, questions their ability to train the algorithm. These findings are consistent with those from our pilot studies where middle and high school students consistently questioned what they are able to do in their role, and how their decision would impact their ability to keep their job. Significantly, students who demonstrated their SPK and DSK when framing the issue, sometimes chose to enact a solution that did not address the sociopolitical impact, either because they feared for their job or did not feel that they had to power, or responsibility to enforce it.

Given these findings, we conjectured that in addition to immersing students in sociopolitical and ethical contexts (through readings, working with real data sets, and engaging in discussions about the effects of our mathematical products on different groups), we must also model the specific components of an ethical argument, and provide ample opportunities for students to engage in the ethical decision-making process from start to finish. Beyond this, if our goal is to promote students’ EMC through a lens of a feminist ethic of care and social responsibility, we must explicitly build these goals and corresponding considerations into our model.

In response to these considerations, we developed the *Ethical Decision-Making in Data Science Protocol* (See: Figure 3, Register et al., under review). Significantly, this model includes guiding questions intended to promote SPK, DSK, as well as other forms of knowledge, and a pluralistic moral disposition including concern for social responsibility and an ethic of care. In addition it prompts a systematic analysis of alternative contexts and alternative consequences at the forefront of their decision making process in order to promote the development of piecewise alternative solutions that protect against the potentially harmful effects of their initial decision. Finally, given the impact that students’ perceived empowerment seemed to have on both the solutions that they offered and their role in enacting those solutions, the protocol further prompts students to engage in a meta-analysis of their perceived empowerment while developing their solutions. We hope that this may allow them to recognize how their perceived ability to enact a solution may impact the characteristics of the solution itself and use this knowledge to center themselves as an agent of change at the systems level. In sum, our ultimate goal is for our students to internalize the components as necessary elements of an ethical argument and continue to draw on them in their future decision making processes, whether in data science or beyond.

* **Finding 3: *Grounding the mathematics instruction in ethical and critical contexts requires that the designers consider the potential implications of immersing students in controversial scenarios*** (Reinke et al., 2022, Register et al., 2022).
* **Response:** ***Cultural Participation Orientation to the Learning Environment***

When conceptualizing an ethical mathematics education for students with diverse and intersecting identities, it is of critical importance to define how we intend to facilitate such learning. This is especially prudent given the controversial nature of such contexts and the diverse perspectives and experiences that exist in any given classroom, contributing to how students choose (or not) to participate in discourse and classroom activities. That is, students bring with them different personal, social, mathematical, and ethical perspectives that must be honored. Given that we prescribe to a feminist ethical perspective concerned with context,

**Figure 3**

*Ethical Decision-Making in Data Science Protocol*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **C0. Context** **C0.1.** What is the proposed D.S., A.I., M.L.+ act/product/process?**C0.2.** What is the purpose of the proposed D.S., A.I., M.L.+ act/product/process? **C0. 3**. For whom/what is the act/product/process intended to benefit?  | **C1. Ethical Issue****C1.1.** What ethical dilemma/moral issue does the act/product/process present? **C1.2.** Is the dilemma related to the * Intent of act/product/process?
* Consequences of the act/product/process?
* Characteristics of the actor performing or promoting the act/product/process?

**C1.3**. For whom does the issue have a significant impact?

|  |  |  |
| --- | --- | --- |
| * Self
* Society
 | * Social Groups
* Marginalized Social Groups
 | * Animals
* Environ.
 |

 | **C2. Relevant Knowledge****C2.1.** What relevant knowledge are you drawing on to make this assessment? * CK: Common/Accepted Knowledge
* SPK: Sociopolitical Knowledge
* MK: MathematicalKnowledge
* SK: Statistical Knowledge
* CSK: Computer Science Knowledge
* GPK: General Professional Knowledge
* DSK: Data Science Industry
* O: Other knowledge: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**C2.2**. Is there anywhere else you should look? |
| **C3. Solution to the Ethical Issue****C3.1**. What is your proposed solution to avoid or reduce the impact of this ethical issue:  | **C4. Moral Justification for Proposed Solution** **C4.1.** What general ethical principles are used to guide and justify your proposed solution?

|  |  |  |  |
| --- | --- | --- | --- |
| * Privacy
* Fairness
* Accuracy
* Accountability
 | * Algorithm Bias
* Transparency
* Accessibility
* Property
 | * Loyalty
* Ecological Impact
* Employment
* Discrimination
 | * Other: \_\_\_\_\_\_\_\_\_\_\_\_\_
 |

**C4.2.** What are the obligations of your role as a \_\_\_\_\_\_\_ (e.g. data science engineer) that have that impacted your proposed solution: **C4.3.** How does your solution attend to the following considerations: * + Consequences of the act/product/process:
	+ Intentions in developing the act/product/process:
	+ Virtuousness of the actor performing or promoting the act/product/process:
	+ Impact on interpersonal relationships (interpersonal empathy)
	+ Social responsibility to promote equity and justice (systemic empathy)
 |
| **C5. Alternative Contexts:** *Given your proposed solution to the ethical dilemma:* **C5.1.** What are different ways to describe the world that would change what we want to do?**C5.2**. What contexts or situations would reduce the positive impact of your proposed solutions?  | **C6. Alternative Consequences:** *If we adopt your proposed solution, what are the potential effects:* **C6.1*.*** *Positive* effects (For whom? In what context?): **C6.2.** *Negative* effects (For whom? In what context?):  | **C7. Alternative Solutions:** *Given these alternative considerations:* **C7.1.** Would you modify your solution based on the above considerations? **C7.2.** What alternative or piecewise solution(s) would reduce the aforementioned negative effects?**C7.3.** What is your justification for these modifications? |
| **C8. Agency/Empowerment:** **C8.1.** How able do you feel to enforce your solution?**C8.2**. How did your perceived ability to enforce the solution impact the solution itself? **C8.3.** To what extent do you feel that your solution attacks the issue at each of the following levels: * + Systems level:
	+ Local level:
	+ Level of an isolated incident:

**C8.4.** Who do you feel holds the greatest responsibility to protect stakeholders from the negative impact of the issue or solution? * + I do
	+ Others do
	+ Others with more power/ability do
	+ Those who are affected most, do
	+ No one, it is the way of the world
	+ Other: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Do you feel this way generally? Or within this specific context? Why? |

identity, and power, it is essential to explore these elements in relation to the topics at hand. Furthermore, a feminist ethic promotes moral pluralism (Weinstock, 1998), characterized by the ethical actors' open-mindedness when faced with competing viewpoints. Thus, it is necessary to consider how we expect learners to participate in activities that are grounded in sociopolitical and ethical contexts and require discourse surrounding controversial topics and scenarios.

 Generally speaking, scholars concerned with equity work often have adopted a Cultural Alignment Orientation towards learning wherein culture is defined as a way of life within a bounded community that is passed down from generation to generation (Hodge et al., 2019). Instructional designs from this perspective attempt to align classroom practices to those from students’ home communities (Hodge & Cobb, 2019). This has caused some resistance, given that the composition of U.S. classrooms often do not reflect separate bounded communities, but rather a collection of intersectional ones. In addition, the realities of globalization, rapid technological advancements and increased global immigration imply that bounded communities no longer exist in society and thus do not translate into the culturally homogeneous classrooms that are more conducive to the methods associated with the Cultural Alignment Orientation (Register et al., in press; Hodge et al., 2019).

In contrast, we adopt the Classroom Participation Orientation elaborated by Hodge and Cobb (2019), which views culture as “a network of local hybrid practices that people jointly constitute as they negotiate their places in specific settings” (p. 863). Through this lens, students develop ways of participating in or resisting classroom practices based on a range of resources, practices, and identities that they bring to the classroom from their home, community, societal discourses, popular culture, and the media (Hodge et al., 2019, p. 863). In other words, the Cultural Participation Orientation views classroom culture as something to be negotiated by students with different experiences and intersecting identities, allowing them to speak to their personal and community experiences, resources, and perspectives. Therefore, rather than starting by aligning classroom practices with those from students' home communities, the Classroom Participation Orientation begins with classroom practices that promote rigorous disciplinary (e.g. data science) learning. From there, the central question seeks to understand how that instruction can be modified, either by adjusting specific classroom practices, modifying activities, or providing additional evidence-based supports that may enable students who draw on diverse resources and identities to participate equitably and substantially (Hodge & Cobb, 2019). That is, the students drive both the discourse itself and define how they collectively prefer to engage in such discourse.

Findings from our analysis of the designed and modified learning environment of EDS indicated that students participated differently in both discussions and activities according to their many intersecting identities (Register et al., in press). In learning environments grounded in ethical and critical discourse, it is of the utmost importance that equitable participation is prioritized in order to ensure that students experience a diversity of perspectives on the effects of data science in society. If this does not occur, we run the risk of perpetuating dominant ideologies and stereotypes, at the expense of nondominant viewpoints. Importantly, equitable participation does not mean that all students participate in the same way or to the same extent, since their identity influenced ways of participating are different. However, it does mean that students participate in ways that promote collective understanding, interpersonal and systemic empathy.

Based on the results of our analysis of the EDS course learning environment, the following design elements (Table 4) are proposed for supporting equitable participation in data science courses that take on a Cultural Participation Orientation toward learning:

Table 4. Proposed design elements for fostering equitable participation

|  |  |  |
| --- | --- | --- |
| **Design Elements** | **Characteristics** | **Justification** |
| Task Structures | Decision making, pluralistic, qualitative. | Facilitate a learning environment that values multiple perspectives, critical, content-based, experience-based, and solutions-based reasoning.  |
| Participation Structures | Small group reporting structure where all students are required to present | Allows non-dominant students the space to have their voices heard, while promoting the provision of space by dominant students |
| Small group talk in whole class discussion | Reduces non-dominant students feelings of incompetence and fosters student empowerment in whole group discussions.  |
| *Select* Discursive Practices  | Co-establish social norms and facilitate a space for students to negotiate them according to their cultural, gendered, and personal resources | Allows students to create a hybridized learning environment based on ways of participating that work for the learners in that context.  |
| Collaboratively define equitable participation as necessary for collective understanding | Promotes student empowerment to participate in the social norm to explain one’s reasoning and to make space for others to do the same |
| Promote rough draft thinking by explicitizing that there are “no experts on ethical data science” in the classroom | Reduces non-dominant students’ feelings of incompetence and fosters student empowerment.  |

The results of these designed structures and practices included 1) the development of a new social norm called “making space” where dominant students observably encouraged their less dominant peers to publicize their perspectives and ideas in class discussions, and 2) students’ belief in the need for equitable participation, collaboratively defined as a means to achieve collective understanding. For instance, in an alternative paper, we discuss the teachers’ hesitation toward calling on specific students in classroom discussions in the EDS course for fear of making students with fragile identities uncomfortable (Register et al., in press). As described, a key solution to this issue came in the form of students’ contributions being treated as diverse and legitimate knowledge that serves to amplify collective understanding of the topic at hand. As a result, the teacher was able to comfortably call on specific students because it came from a place of seeking a valuable perspective for others to consider. As time passed, the students began to internalize this framing and typically quiet students began to contribute without prompting to have their perspectives heard.

 On a final note, with regard to privileged student populations, the intentional discursive moves and designed structures of the EDS course enabled the dominant students to reflect on their positions both in society and in the classroom as well as to value and encourage the voices and perspectives of others. Thus, it is essential to accept that privileged students are very capable of giving space, but they need the impetus to do so along with ongoing opportunities to reflect on why it is important. However, creating such an environment entails explicitly attending to the design elements that privilege some and restrict others in the classroom, industry, and societal contexts. Continued commitment to such initiatives by educators may help to dismantle gendered notions of STEM and data science success, as well as promote a communal social orientation both within and beyond the classroom

**Contributions to the Field**

In sum, this chapter has offered an overview of both the findings and products of a large Design Based Research project intended to illuminate how we might design for students’ Ethical Mathematics Consciousness in data science. As a contribution to the literature, it offers some potential first steps for developing a data science industry concerned with social responsibility and the deconstruction of systemic injustices caused or reproduced through data science. Specifically it offers the ERiM Principles and the EMC Analytic and Design frameworks for guiding the design and development of course activities and structures that seem to promote ethical decision making in data science contexts, equitable participation among participants of ethical data science learning environments, and by describing a general structure, tools, and activities for a course intended to promote students’ critically conscious ethical decision making in Data science. Furthermore, it offers an *Ethical Decision-Making in Data Science Protocol* to be used and modified by the mathematics and data science education communities in order to promote such decision making in data science contexts, using a structured approach to ethical argumentation. We see these contributions as significant, given that neither an ethical decision-making protocol nor curricula seem to exist at this time in the literature, despite the need for tested, refined, and ethically grounded course materials in data science.

**Future Research**

The nature of Design Research is iterative in the sense that each implementation should highlight necessary modifications to the design. These modifications are often done in real time during the implementation phase of the design cycle, but are not always refined. In addition, findings from the retrospective analysis often illuminate flaws in the initial design that either may not have been recognized or that were not feasible to modify in real time. Thus, the next steps for this research are to conduct further retrospective analyses for the purposes of modifying the EDS course.

With regard to materials, the rapid impact of new BDA technologies (e.g. open access generative Artificial Intelligence), warrants that we continuously update the course and interview materials to reflect relevant ethical dilemmas in the industry. Thus, we plan to develop a series of new ethical data science tasks that align with more recent technological advancements and ethical dilemmas in the field.

In sum, this chapter offers an overview of the products and findings of a long-term project committed to the development of ethical data science learning experiences. The nature of teaching, learning and the data science industry itself are constantly changing and adapting to the world around us and the realities of globalization. Thus it is natural to expect that each iteration will provide evidence of new ways of teaching, learning, and engaging in discourse that serve to promote students’ development of EMC in data science. Our commitment to this work is to stay up to date with both these changes and innovations to provide materials and instruction theory that support innovative and ethical learning experiences. It is our hope that others in the field will also take up this call, either by contributing new ideas, or by leveraging the findings of this work for their own context.

As such, this article concludes with a call to action for the mathematics and data science communities to begin thinking about and designing for students’ critically conscious ethical decision making. Given the rapid expansion of data-based decision making processes in society, the predominantly privileged demographic of current data scientists, and the role of mathematics and data science education in the development of future data science teams, it is imperative that we center ethics in our mathematics and data science instruction. That is, students must be regularly exposed to both the benefits and drawbacks of the methodologies associated with BDA, and must be given opportunities to practice making ethical decisions that would protect those at risk of harm.

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##

## Appendix

## Table A.1. Major Normative Ethical Perspectives/Systems with Feminist Critique

|  |  |  |  |
| --- | --- | --- | --- |
|  **Major Ethical Systems and Perspectives** | **Ethical Actor’s Primary Concerns/Tenets** | **Ethical Actor’s Primary Unit of Analysis** | **Feminist Critique** |
| 1. **Teleological/Consequentialist Theories**

Primarily concerned with the ***consequences of ethical decisions***. Does the end justify the means? Can align with Moral Absolutism, Relativism, or Pluralism.  |
| **Utilitarianism***Greatest Good**Henry Sidgwick, Jeremy Bentham, John Stuart Mill,**Harriet Taylor Mill* | The ethical decision is the one that promotes the greatest happiness for the greatest number (i.e. the majority). | Consequences of the act, who and how many it affects.  | **Supports** notions that: (1) no persons’ preferences are more valuable than another’s; (2) Moral character is restricted by unequal social arrangements. **Rejects** (1) utilitarian *impartiality* for ignoring emotional connections and relationships; (2) binarism; (3) traditional notions of female’s societal role; (4) *consequentialism* for failing to critique oppressions that are not reducible to harm.  |
| **Egoism***Self-Preservation**Henry Sidgwick, Ayn Rand* | People act out of self-service, which is natural and moral. i..e. The primary reason that someone does any action is self-serving by bringing themselves happiness or other personal benefits.  | Consequences of the act, does the act benefit the agent? | **Rejects** lack of attention to the other (i.e. an ethic of care). |
| 1. **Deontological Theories** *(Rule and Duty-based)*

Primarily concerned with ***a persons’ duty***, where “duties” can be drawn from divine-beings (divine-command), nature (natural law/rights), observation (Kantianism), or contracts (contractarianism/social contract) made among members of society. The end result is not as important as the moral intent of the decision or action. Often (but not always) aligns with Moral Absolutism. |
| **Kantianism**C*ategorical Imperative**Kant* | Ethical actions are based on the categorical imperative. That is, an action is made when it is considered objectively necessary, without reference to any other purpose.  | Intent of the act, is it necessary? | **Rejects** an ethic of duty due to(1) its grounding in universal and absolutist principles and rejection of embodied experiences, characteristics, and relationships; (2) its separation of rational capacities from emotional ones, typically subjugating the latter; (3) its over-idealization of rationality and choice.  |
| **God Based Ethics:** *Divine Command Theory**Plato* | Actions are considered right or wrong based on God’s commands.  | Intent of the act,God’s will | **Rejects** the universality of identity, experience, and human rights (which even when de-gendered, often stem from Western values). |
| **Natural Rights and Natural Law Theories***Universal, fundamental, inalienable rights.* *Cicero, Saint Thomas Aquinas* | Notions of right and wrong are inherent in people and are not created by society or law. ***A decision is moral if it furthers or preserves human life.*** Natural rights are universal, fundamental and inalienable, and thus independent of the laws or customs of a culture or government. Natural laws are governmental rules intended to preserve natural rights, and may be formulated through a social contract (see below).  | Intent of the act, does it preserve natural rights? | **Reject** the universality of identity and experience. |
| **Moral Contractarianism** *Social Contract Theories**Marx, Thomas Hobbes. Thomas Donaldson, Thomas Dunfee* | People will do whatever is required to survive in a state of nature, where rules and laws do not exist. Thus, a persons' moral and/or political obligations are dependent upon an agreement (contract) among rational, free, and equal members of society (incl. Laws, rules, norms). ***Morality then, is the set of mutually beneficial rules that rational people will agree to obey***.. Importantly, the terms of the ***social contract*** are decided behind “a veil of ignorance” so that unfair advantages are neutralized and benefits are received equally. | Intent of the act. Does the action align with the social contract? | **Support**: (1) all persons have intrinsic value whose interests should be respected; (2) ability to critically assess relationships; (3) applicability to women in vulnerable positions; (4) adaptive preferences based on conditions of autonomous choice, independence, and dialogical reflection (see Rawls Theory of Justice).**Rejects** the idea that all stakeholders have access to the social contract (e.g. children, disabled community, caretakers, etc.)  |
| **Rawls’ Theory of Justice***Legal Justice**John Rawls* | In the context of criminal justice in a liberal democracy, ***an ethical society is one in which the principles of justice are founded in a social contract***. Without a social contract among members of society, some may receive inequitable opportunities or treatment. ***Thus, the primary concern of justice is fairness.*** | Intent of the act. Fairness of the act, rights. | **Supports**: Adaptive preferences based on conditions of autonomous choice, independence, and dialogical reflection But rejects the idea that all stakeholders have access to the social contract (e.g. children, disabled community, caretakers, etc.)  |
| 1. **Virtue Ethics**

Primarily concerned with the ***virtue and moral character of the actor***. Can align with Moral Absolutism, Relativism, or Pluralism |
| **Eudaimonism***Traditional Virtue Ethics**Aristotle* | Primarily concerned with the virtue and moral character of the person. Thus, virtue ethics looks at the ***virtue of the person carrying out the act*** as opposed to duty, rules, and/or consequences of the act. e.g., “to be good, I must do good things, and if I am good, I will do good things.” | Moral characters of the actor.  | **Supports**: (1) Rejection of ethics as abstract and universal; (2) rejects dichotomy of reason and emotion; (3) does assume that all humans are essentially equal; (4) importance of emotions and interpersonal relationship; (5) virtue as it relates to specific contexts; **Rejects**: (1) ethics of care and virtue as distinct and separate; (2) lack of attention to “***burdened virtues***”: those that fall short of eudaimonism, but are necessary for those living in oppressive situations to resist and survive, but may subject the individual to vulnerabilities (i.e. whistleblowing, activism, etc.). (3) can place overemphasis on the self without consideration of the other. |
| **Ethics of Care***De-gendered Moral Traits**Feminist Theorists, Annette Baier, Nel Noddings* | Relational and context bound approach to morality and ethical decision making. Critiques solely masculine views of morality and virtue. Values feminine virtues typically exemplified by women, such as caring for others, patience, nurture, self-sacrifice, etc., that have been marginalized due to society’s devaluation of the contributions of women. It emphasizes the importance of solidarity, community and relationships over universal standards and impartiality. | Relations | **Supports:** (1)an ethic of care over duty, (2) rejection of solely masculine views of morality and virtue**Rejects:** Notions of (1) all women as caretakers, (2) binarism, (3) traditionally feminine traits as more valuable than masculine traits.  |
| **Agent-Based Theories***Model Agent**Michael Slote* | Based on our intuitions about admirable character traits in those that we admire and see as moral exemplars. Such intuitions thus depend on our ethical judgements about the inner life of the moral exemplar.  | Moral character of the model agent.  |  |

Sources: BBC (n.d.); Chonko (n.d.); Freire (1970/2018); IEP (n.d); King (1991); Levinas (1969, 1997); Noddings (1988); Mastin (2009); McCartney et al., (2015), Puka (2005); Saylor Academy (n.d.); Shor (1993); Stanford University (n.d.); Weinstock (1998).