



## **How engineering students think about the roles and responsibilities of engineers with respect to broader social and global impact of engineering and technology**

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# **How engineering students think about the roles and responsibilities of engineers with respect to broader social and global impact of engineering and technology**

## **Abstract**

Understanding the social, environmental, economic, and political impact of engineering is an important aspect of being a professional engineer. Responding to this need, engineering programs increasingly offer engineering ethics education. However, courses in engineering ethics as well as research on students' developing sense of engineering ethics often emphasize the micro-ethics of research, mentoring, and publications. In comparison, research is limited on how future engineers understand the social, ethical, environmental, economic, and political impact of their scientific and technological contributions. In this manuscript, we present 2 case-study accounts of how future engineers think about an engineer's responsibility towards the social and global impact of their contribution. The case studies draw from video-taped semi-structured interviews with engineering undergraduates. Our case-study analysis suggests that how some engineering students construe an engineer's responsibility depends on the particular issue at hand (weaponized drones versus malfunctioning bridges, for example), on their sense of self as a future engineer, views about what is engineering, sense of nationality, emotions, empathy, and ideologies/narratives available to them through participation in the world at large. We argue that students' views towards macro-ethics of engineering are sensitive to context, and that there's need for further research on how identity, epistemology, and emotions are entangled with an engineers' ethical view.

## **Introduction**

As part of their jobs, professional engineers engage in ethical, environmental, social, and economic negotiations with other engineers, with managers, and with the public; they need to understand the social impact of new technologies in a global context<sup>1-12</sup>. Responding to this need, engineering programs increasingly offer engineering ethics education<sup>3,12-17</sup>. However, courses in engineering ethics as well as research on students' developing sense of engineering ethics often emphasize the micro-ethics of research, mentoring, and publications with limited emphasis on the social, ethical, environmental, economic, and political impact of their scientific and technological contributions<sup>18</sup>. As the world becomes more connected, the need for future engineers to understand the cascading impact of engineering on the socio-economic-political fabric of society has only become more acute. Engineering education researchers, in turn, need to understand how future engineers think about the interaction of technology and society and their own role in that interaction.

Another feature of ethics courses and textbooks is their focus on professional codes of ethics, frameworks for ethical analysis, and the application of these codes and frameworks to various case studies within engineering practice. While case-based instruction has been productive in some ways, it has tended not to include an explicit focus on students' identities (disciplinary and otherwise) and emotions. To be clear, many courses do include class discussions pivoted on particular case studies during which students' identities and affect likely influence the discussion; and responsive instructors probably attend to these elements of the discussions. What we are pointing out is a lack of *explicit* attention to these elements in the design and implementation of curriculum. Similarly, research on students' developing moral and ethical reasoning also tends to focus on "cold" cognitive, rationalistic, or stage-based models of students' development, rather than capturing the emotionally-charged dynamics of their in-the-moment reasoning<sup>3,10,17,18</sup>. In this manuscript, through case-study analysis, we present potential pathways towards including affect and identity in how we model engineering students' moral and ethical reasoning about socio-scientific issues.

Specifically, we present two case-study accounts of how future engineers think about an engineer's responsibility towards the social and global impact of their work. The case studies draw from video-taped semi-structured interviews of two undergraduate students whom we'll call Tom and Matt. In the interviews, Tom and Matt reflected on the use and impact of weaponized drones in the US war in Afghanistan. Through investigating how they think about the social impact of drone warfare and how they think about the responsibility of engineers involved in the design of drones, we show how, in some cases, students' views towards the social responsibility of engineers is coupled with aspects of their identity, their emotions, their senses of empathy and agency, and ideologies/narratives available to them through participation in the world at large.

In the following section, we present our data collection methods and analysis methodology. Then we present the two case studies, followed by a discussion contrasting the two cases and drawing out the implications of this work for research and instruction.

### **Data Collection and Methodology**

Our data corpus consists of 9 videotaped interviews with junior/senior engineering majors and engineering graduate students recruited through targeted outreach to the Science, Technology, and Society (STS) program at the University of Maryland, College Park (UMD), the Engineering without Borders group at UMD, and the Women in Engineering group at UMD. Students who participated in the interviews were compensated \$20 for their time.

The interviews were meant to be open-ended and ill-structured, following themes that seemed salient to the participant. The interview "prompts" as such were designed mostly to provide ways to get students to start talking about some of these themes. Example prompts included asking

students about their journey into their chosen major, their experience with STS/ EwB/WiE programs (as relevant), their interest in socio-scientific issues, and how they saw the role of ethical reasoning in their future profession as an engineer.

Brief field notes taken after each interview helped in the preliminary data selection. Two of the interviewed students, Tom (a junior-year engineering major) and Matt (a junior-year computer science major), talked about weaponized drones as part of their interview. They had written about this topic in their sophomore year as part of a capstone research project in the STS program. Besides the thematic congruence, another thing that caught our attention was that both students regarded drone warfare to have negative consequences but, to different degrees, wanted to absolve the designing engineers of bearing responsibility.

One of us generated a content log of the interview, e.g., a summary of every ~2 minutes of the interview conversation. After this we viewed the video in our research meeting as a group with the objective of understanding what constructs contributed to Tom's and Matt's construal of engineers' responsibility. We analyzed the content of participants' responses to the interview prompts, loosely drawing on microgenetic learning analysis<sup>19</sup> which emphasizes context-dependence of ideas and has a commitment to teasing apart fine shades in the meaning of an utterance. We also drew on tools of interaction analysis<sup>20</sup> to attend to participants' gestures, posture, and para-verbal aspects of speech such as tone, prosody, register, etc. However, we don't use the full machinery of interaction analysis in modeling the interview as a jointly constructed interactional event between the interviewee and the interviewer. Similarly, the analysis here does not delve into systematically identifying knowledge elements as in microgenetic learning analysis. As such, our analysis is informed by knowledge analysis and interactional analysis but does not draw on the full machinery of either method. We took notes of our conversations at the meetings, and generated analytical memos to capture our preliminary model of Tom's and Matt's notions of engineers' responsibility. Subsequently, we reviewed the data systematically looking for instances that confirmed or disconfirmed our emerging understanding.

We did not collect demographic information on the participants in the interview. We can glean from some of the information in the interview conversations that both Tom and Matt, who we focus on in this paper, were brought up in the United States. During the interview, Matt spontaneously brought up the issue of physical disability, and we do attend to that in our analysis. Based on how they presented themselves, the interviewer (a South Asian male who immigrated to US 15 years ago) tacitly assumed they were both Caucasian males. We have no information on other aspects of participants' identities such as sexuality, socio-economic status, specific political affiliations for either Tom or Matt and we don't have information on Tom's identity with respect to ability. We do not systematically attend to race and gender in our initial analysis. However, in the discussion section we speculate on how we can see the unfolding

conversation in the interviews as lending itself to gender-based analysis and how participants' statements could be seen in the light of narratives and stances that permeate public discourse on the topic of drone warfare. These comments are speculative and could be seen as not fully supported in the data; and yet, we touch on these because we feel that looking at the data from a gender, race, nationality, and public narratives could provide useful insight and tell stories about the participants' perspective that aren't present in the principal analysis so far. We hope to develop these perspectives further in future work.

### **Case Study 1: Why Tom argues that engineers aren't responsible for the negative consequences of drone warfare**

Tom had written his STS capstone project on the dehumanizing effect of autonomous warfare on society. While describing his experience in the STS program, he mentioned that the capstone project was the most enjoyable and productive part of the program for him. In his project presentation, he concluded that drones "will dehumanize society ultimately" and "make us less sensitive to war" because the drones have cameras on them which provide a close-up view of war and death all the time. Tom mentions how soldiers can remotely kill using the drones and that will ultimately dehumanize them to their own actions. Asked later, Tom mentions that engineers definitely play a role in the design of autonomous warfare technology, but emphasizes that they are not responsible for the negative consequences of drones. This assertion is surprising because Tom reiterates multiple times during the interview how technology and society are strongly coupled and influence one another. Below we present a few themes emerging from his interview that shed light on his reasoning.

#### *Aspects of Tom's identity and emotions are intertwined in his reasoning about drones*

The topic of autonomous warfare had some emotional and personal salience to Tom. When asked how he came to decide on this as the topic for the report, he mentioned having had conversations about the use of technology in warfare with relatives who are serving in the military. "Dehumanizing," the word he used to describe drone warfare, is laden with emotional connotation. Tom uses personal pronouns such as "us" and "our society" in describing those on whom the drone warfare is having negative consequences. Describing one such scenario Tom mentions how in his research paper he had a section on the use of inaccurate drones that end up killing civilians in places such as Pakistan. He says that it "might come to a point that we might be in a potential war because of these drones, their impact not just on our society but on other people's societies." While mostly Tom talked about the impact of drone use on American soldiers and American society, this bit of conversation highlights that he was perhaps also thinking about the effect of drones on those under fire.

Tom's sense of self as an American citizen seemed salient to him throughout discussion of drone warfare. We see further evidence of this later in the interview when Tom justifies America's

need for manufacturing and having drones. Asked if engineers should refuse to design drones given their negative impact, he answers:

That goes into our nation's defense and us being prepared. (smiles) I think it's important to have this kind of technology so that if we ever need to use it, we can. But I don't think we should be using it entirely for the purpose we are...we shouldn't be using it to the extent we are. It's causing a lot more problems than helping. It's important to have them and keep building these technologies because that's the only way we are going to stay a nation who's respected (smiles). You know what I am saying.

While Tom considers autonomous warfare to have a dehumanizing effect on American society, he thinks it still plays an important and essential role. He values America's military prowess and considers it important that America maintain its status in the world. New technologies can aid in maintaining that status quo. The problem Tom sees is in situations where such technology might be misused. He also mentions that access to these novel forms of warfare might serve the purpose of deterring other countries from trying to harm America, without needing to actually use those technologies.

Tom's disciplinary identity as an engineer also plays a role in his reasoning. When first posed the question of why he thought engineers don't shoulder any blame for the negative consequence of drone usage, he smiles sheepishly and says that he is an engineer and so is biased towards that opinion:

I am a little biased because I am an engineer (smiles, looks to the side). Personally, it's hard to blame the engineers because, you know, ultimately they are building technology to help us improve as a society. They don't have any mal intentions with the technology they are building. If someone takes their technology and uses it, you know, in a bad way that's more on the person who used it. That's my personal opinion (shrugs shoulders) anyways.

Asked if in his future job he personally will have to grapple with the social impact of his designs, he says that he would like to be involved in that discussion. But says that engineers might be limited by their mindset:

Engineers can be closed minded. We are very technically oriented. We don't really think a lot about our impacts...I think it's just how our brain works...Because I don't come from an engineering [familial] background, I think about it. I would like to have some say in how [my designed product] is distributed and used.

### *Entangled conceptions of blame and responsibility*

What also stuck out to us was that while our questions to Tom were phrased using the term “responsibility,” his responses often used the term “blame.” In Tom’s reasoning these two terms were used interchangeably. This is important because blame can often have negative connotations through association with wrong-doing, deserving of punishment, etc. If Tom was construing the question of whether engineers bear some responsibility for the cascading impacts of their designs in terms of blame and culpability, his responses were likely colored by the very human desire not to be blameworthy. Clarifying this later in the interview, Tom mentions that engineers should be aware of and take account of the social impact of their designs, but ultimately they should not be blamed for any negative consequences.

### *Tying accountability with intent*

In the last quote of the previous section, we note how Tom’s focus was on the intent of engineers. He distinguishes this from the intent of governments, military, manufacturers, and those who might use engineers’ creations for purposes other than those for which they were created. At multiple points in the interview he mentions how the users are the ones who are responsible for the impact of that use. He feels that engineers should be aware of the impact of the technology they are designing and build it so that it can only be used for that purpose. There is further nuance to his reasoning:

The engineers are building these drones but they are not the ones using them. So, it’s kind of a question of who is responsible. Is it the one who is using them, or is it because, you know, they would never be using them if these engineers hadn’t made them.

This emphasis on intent, we speculate, is connected to the earlier issues of blame versus responsibility. If Tom is conceptualizing the situation as one of deciding who shoulders the blame, it is possible that he is thinking about active wrong-doing which often involves intent.

There is, however, some subtlety to Tom’s conceptualization of blame and intent. Asked about the boundaries of engineers’ responsibility, he brings up the case of a bridge collapsing due to a design flaw. In this case, Tom says that the engineers who designed the bridge shoulder the blame and should be held accountable since their mistake caused the damage:

There’s an engineering code of conduct. I am not sure exactly what that states. But I think it holds engineers liable for things that they build. If an engineer builds a bridge and it collapses, that’s obviously their fault. But if an engineer builds a weapon of mass destruction and they distribute that, you know, whose responsibility is that if they use it in like a bad way.

For Tom, while engineers aren't to be blamed for how their products are put to use by end users, they are responsible for technological failures that result in harm when the product is used for its intended purpose.

### *Role of Agency*

Another reason Tom absolves the engineers of blame for the negative consequences of autonomous warfare is that he thinks they are powerless to change how the system works. At multiple points in the interview, he articulates that governments and other regulatory institutions are the ones who dictate whether and how technologies are used. He says that engineers should try to project how their products can be used and include design features that ensure safe use of the product; engineers can suggest particular restrictions and regulations on their use but their role and their power in implementing these recommendations are limited. For him, the agency of engineers in directing the use of products is also limited by people wanting to do what they are told not to. He notes that people cannot be controlled, and as such it is the end user who has the ill intent (in the case of using a product for violent or other unintended use) and they shoulder the blame. Here again we found Tom drawing on the notion of intent in making his argument.

### **Case Study 2: Why Matt argues that engineers are responsible but not blameworthy for the negative consequences of drone warfare**

Matt also wrote his STS capstone report on the consequences of drone warfare, arguing that drones have a negative impact on society. Matt regarded engineers who design tools of autonomous warfare as shouldering responsibility but not blame for the impact of their designed products. At one point, he even argued that every citizen is in some way responsible for these impacts. Like Tom, Matt's identity, emotions, and conceptualizations of blame, responsibility, and agency influence his arguments, as we now show.

### *The issue of drone warfare was emotionally charged for Matt*

The issue of drone warfare was important for Matt. We glean this from his facial expressions, intonations, and verbal stress during the extended discussion on this topic. Many times he just shook his head in disapproval stating how drones are having a negative impact on those under fire. And he felt that drones are causing people around the world to have a negative view of the US, which he thought to be appropriate (though undesirable) given the situation. Describing his research project for STS, he says:

Drones made the war worse and it made more insurgents rise. It caused widespread public dissatisfaction with the American foreign policy and the war itself. Especially in the country that was being monitored by drones, bombed by drones. One thing is that they never knew when they were gonna be attacked. They had to live in constant fear, which none of us in the United States can imagine really. Because at any point any one of



them could die. Because the drones are notorious for not - I mean, they are machines, they do what they are told. They can't distinguish between friend and foe. One of the other things was that when they would actually see the recon drones overhead, it would basically terrify them. The fear and their dead family. It really caused the war to just keep going forever because they are never gonna stop fighting.

Matt goes on to describe how many of the insurgents started when they were young, driven by how their family and friends were killed by the drones. Elaborating on his views about the war he says:

I don't think the war is (lifts arm up and slaps it down) productive at all (smirks). That's just my opinion. As you can see I took a very anti-drone stance.

One aspect that stands out in Matt's reasoning is the high level of empathy for those who live under drone attacks. This is the principal narrative around which drones are labeled as bad and unacceptable by Matt.

*Aspects of Matt's identity with respect to physical ability influence his sense of agency as an engineer*

Early in the interview, describing how he chose his major, Matt talks about being diagnosed in his childhood with an illness that prevents him from standing or walking for long or engaging in sports. He mentions how he enjoyed competition, and thought that computer science will present him with challenging problems without necessarily requiring physical exertion. His choice of school was also dictated by the need for proximity to home, given his physical limitation.

Matt feels that physical limitation has also impacted his political involvement. He mentions that he used to be more interested in politics, but college studies and physical limitations have gradually caused him to lose interest. He feels disconnected from the political process. In spite of this, Matt often veered into making political commentary in the interview, on the electoral process, different forms of government, hackers, cyber security, Wikileaks, distributed denial of service attacks by Anonymous, etc. Matt also mentions how a single person cannot have significant political impact, a view he feels most of his college friends share. This sense of limited agency of himself and other individuals is likely connected to how he sees the roles and responsibility of an engineer with respect to socio-scientific issues, as we elaborate later.

*Matt considers engineers/scientists responsible for social impact of their designs but does not blame them*

Since Matt was a computer science major, we phrased the question probing responsibility in terms of computer scientists (or computer scientists and engineers). Asked if computer scientists

who are involved in the design of weaponized drone technology are responsible for the negative impact, Matt says:

Yeah, they are absolutely responsible (almost laughing at the question) in some way. I mean they are just doing their job. If they refuse to do it, they would lose their job. And that doesn't help anyone. So, in some way they are responsible because their action is providing what is required in order to kill those people, but I don't really blame them. At all. Because if it wasn't them, it would be someone else. In a way they are [responsible]. At the same time they aren't. It doesn't make sense, but that's my opinion.

In his statement Matt distinguishes between blame and responsibility. He thinks that the scientists designing weaponized drones do bear some responsibility for the social impact of their action, but he refuses to blame them. His argument for not blaming them is in part based on the practicality of the situation rather than on personal ethics. Through this portion of the conversation, Matt also seemed a bit uncomfortable, often hedging his responses, many false starts in his utterances, and at times saying that maybe he shouldn't get into this topic.

Asked "Who bears the responsibility of the negative impact?" Matt unequivocally answers that the military is responsible because they are the ones making the decision to use the drones in spite of knowing the limitations in the accuracy of the technology and seeing the negative consequences of their actions, even towards their own goals. Here, we also see how the intent vs impact is playing a role in Matt's argument. He considers the military responsible because it is their prime intent that is driving the use of drones in war. He mentions how this is driven by the desire to reduce the casualties of American soldiers.

The interviewer poses a hypothetical to Matt about the ethics of researchers at universities taking funding from the military. Matt's argument here was that researchers would be aware of their actions if they are receiving military funding. He says it is okay if the weapons are not meant to kill civilians but they end up killing civilians by accident. So while the intentions are good, in practice drones cause great amount of civilian deaths which is unacceptable. Ultimately, he flags this as a grey area.

*Matt thinks that engineers have limited agency over the socio-political impact of their designs*  
A recurring theme in the interview was that engineers and scientists have limited agency over the regulation, use, and impact of their designed technology. We see this in his earlier quote where he says that a computer scientist who refuses to work on drone technology because of personal ethic is only hurting themselves because someone else will do the job. This aligned with his views that a single person can't really have a political impact. We also feel, but cannot establish definitively, that this is connected to Matt's sense of disability, which limits his own agency for political action.

We would like to wrap up our description of Matt's views with one comment that stuck out for us. Talking about the issue of who is responsible for the negative social impact of autonomous warfare, Matt extended the sphere of responsibility:

It's a hard way to say this but everyone involved is to blame in some way. No one's blameless. Even the American public. The American public should be much more upset about this than they are. But I can't be one to talk because I don't get involved in politics.

We can't capture in transcript Matt's dejected and resigned emotion during this entire utterance, but this partly sums up Matt's view on the notion of responsibility.

### **Discussion:**

Through the case studies of Tom and Matt we want to highlight how emotions and identity play an influential role in how students reason about ethical responsibility and blame in an affectively charged ethical context such as autonomous warfare. For many engineering and science students, these contexts will not be mere hypotheticals in their future professional lives. More important, it is likely that when ethical dilemmas arise in their professional lives these are going to be emotionally charged situations. As such it is important for us to include emotions and identity within models of how engineers actually think and should think through ethical dilemmas. Most research literature on ethical reasoning, as well as textbook treatment of ethical case studies typically draw on "cold" and rationalist cognitive models. For both Tom and Matt, the issue of autonomous warfare was emotionally charged and connected to aspects of their identities, but in interestingly different ways.

In Tom's case, his identification with American interests and society and with engineers influenced his reasoning about how he attributed responsibility to engineers. This is linked to how he conceptualized the negative impact of autonomous warfare: his focus was on the dehumanizing effect on American operators and American society. Matt, on the other hand, empathized strongly with those who are the target of drone warfare. During his interview, he also ventured into many political topics, reflecting his awareness of and interest in global politics. His self-identification as being physically disabled likely influences the limitation he feels in political action, which spills over into a general sense that individuals can't have political impact. As such he argues that while scientists and engineers are responsible for the impact of their actions, they are just doing their jobs and should not be blamed for it. Both Matt and Tom think that scientists and engineers should not withdraw from designing drones; but Tom's reasoning is predicated on protecting American interests, while Matt's argument draws on the practical futility of such withdrawal by an individual since some other scientist/engineer will take on that role.

We want to take a turn here to speculate on how social construction of gender and public narratives in the US around the issue of drone warfare could inform our interpretation of our conversation with Tom and Matt. In the context of the interview conversation, Tom seemed to strongly identify with American interests and the idea that drone-based technologies are needed to protect American supremacy in the world. The idea of nationalism, patriotism, and militarism is, however, intimately connected with gender. Our military and political systems tend to draw power from patriarchy; are male-dominated spaces; and embody stereotypical notions of masculinity<sup>21,22</sup>. The identification of masculinity with the role of protection overlaps with how militarism is also seen as serving the function to protect<sup>21</sup>. Tom's statements, then, can be interpreted as the playing out in this instance the broader social connection between gender and militarism. We aren't saying that Tom is saying this because he is male, nor are we saying that he is aware of these connections. In those moments, he is (perhaps unintentionally, tacitly) aligning himself with the White male patriarchy, an alignment that might or might not be reinforced by his status as a White male. Our point here is that the microcosm of the interview can be seen as an interactional space where the gender-nationalism connection that shapes the public discourse around militarism and patriotism is being played out.

In a similar vein, we can see both Tom's and Matt's statements as reminiscent of public discourse in the US around drone warfare and the general ways in which the purpose of engineering is seen in society. Since Tom and Matt both did a research project on the social impact of drone warfare, it is likely that they are exposed to the stances and arguments that are part of the national and global conversation about drone use in wars. We don't mean to suggest that they are simply parroting others' views, but that in their voice we can notice stances that are commonly available in the public discourse: drones have a dehumanizing effect on society, the need for US to protect against terrorist threat, everyone being complicit in the war effort, drones leading to more insurgents, engineers as serving society, government as the only entity responsible for regulating, etc. Thus the conversations with Tom and Matt can be seen as embedded within the national discourse in the US around war and engineering and as an example of that national phenomenon playing out in a local, private setting.

We want to be clear here that we are not trying to paint Tom's or Matt's reasoning as superior; it is our explicit intent to remain neutral to the specifics of their arguments. Our purpose here is descriptive. This is important since readers of this manuscript might themselves have strong opinions about the issue of autonomous warfare. There is another caveat: the interview is a jointly constructed event, shaped by the prompts and reactions of the interviewer as much as by Tom's or Matt's utterances. So, that which is highlighted in the conversation might also serve to hide other aspects of an individual's views. For example, maybe if probed, Tom would have said a lot more about the effect of drones on those being bombed; but this just happened not to be the focus of his research paper. And the interviewer doesn't probe for that, which might make it difficult for Tom to bring it up on his own, given the norms of an interview.

While the specifics of Tom's and Matt's case are different and it is difficult to draw any generalization based on two cases, we think that the entanglement of identity, empathy, emotions, agency and conceptualizations of blame and responsibility are likely to play a role in how engineering students develop their understanding of their future professional responsibilities.

Instructionally, we feel that ethics courses should include more discussions of such emotionally charged and geopolitically complex ethical issues since many of our students are likely to face these issues in their professional lives. As engineering courses become more diverse, it is likely that engineering classrooms include a greater diversity of backgrounds and perspectives. And it is likely that discussions around these topics will be emotionally charged for students and draw on various aspects of their identity. In order to design instructional strategies to facilitate such discussions in a safe yet productive way, there is a need for more research in understanding the socio-cognitive dynamics of how engineering students think about complex socio-scientific issues.

We have ventured to speculate how the gender-nationalism-militarism connection and public narratives around drone warfare and engineering are yet other lenses through which we can view the interview interactions. But these are exploratory interpretations that we hope to flesh out in our future work. While we don't think we can tell a complete story of how Tom and Matt (and other engineering students) think about the roles and responsibilities of engineers on socio-scientific issues of global social and political impact, we feel that including these additional lenses enables us to see more facets of the phenomenon than we would otherwise. Another reason to explicitly attend to these dimension, even while being unsure of our own footing on these arguments, is that we feel not doing so would contribute to silencing (and hence, marginalizing) how gender, race, and public discourse play a role in the phenomenon we study in education research. In future work, we plan to collect demographic data which might help us refine our claims. As initial explorations, the arguments presented in the paper are bound to have inconsistencies and incompleteness. Acknowledging that, we humbly hope to pursue more detailed analysis in future work.

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