Integrating Character Formation into an Introductory Engineering Design Course

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Abstract: This paper presents an evidence-based intervention to integrate character formation into EGR 101 *Introduction to Engineering Design and Communication*, a required first-year course in Duke University's Pratt School of Engineering with over 300 students. In collaboration with a new ethics initiative, *Character Forward*, we sought to make character central to students' early experiences of engineering by introducing specific character traits and embedding reflection on those traits into the design process. Drawing on virtue ethics and character education, we identified five traits—respect, curiosity, resilience, integrity, and responsibility—as aligned with the iterative and collaborative nature of design in this course. Then we developed interventions to address these traits. Piloted in Spring 2025 and refined for Fall 2025, our interventions were evaluated through surveys comparing control and treatment sections. While our assessment tools faced various limitations, we did find that 80% of students reflected positively on the interventions. Our findings inform efforts to move engineering ethics education beyond compliance-based models toward pedagogies that intentionally cultivate character.

1. Introduction

With the rapid development of new technologies, we are preparing engineers for an increasingly unfamiliar world—one we cannot fully predict. What challenges will they face? What expertise will they need? As we educate the next generation of engineering leaders, it is essential that they are prepared to make wise decisions decades from now, in contexts shaped by technologies and social dynamics that we can scarcely imagine.

To prepare students for this future, we cannot rely solely on professional codes of conduct, which may become outdated or fail to inspire moral motivation. We can, of course, introduce engineering students to ethical reasoning and theory, and this may help them thoughtfully navigate the dilemmas they will encounter. Yet knowing how one *ought* to act does not guarantee that one *will* act accordingly. We know we shouldn't eat processed foods, yet we do. We know we should listen attentively and receive criticism graciously, yet we struggle to. Such failures suggest that moral lapses often stem not from ignorance, but from poor habits of action and mind—or, more precisely, a lack of character. If we can help engineers develop excellent character, we believe they will become leaders capable of making wise decisions amid the uncertainties of the future.

To that end, we sought to integrate character formation practices into the introductory engineering course in Duke University's Pratt School of Engineering, called EGR 101 *Introduction to Engineering Design and Communication*. In collaboration with a new ethics initiative in the engineering school, *Character Forward*, we aimed to make character central to students' early experiences of engineering by embedding reflection on specific traits into the design process. We identified five traits—respect, curiosity, resilience, integrity, and responsibility—as aligned with the iterative and collaborative nature of design and mapped these traits onto the five phases of the course. Students received instruction on each trait during the

corresponding phase and completed structured reflections. Our goal was to investigate how these interventions influenced students' virtue literacy and character formation, and whether they continued to view technical skills alone as sufficient for engineering excellence. We also sought to evaluate how best to assess character and learn from student responses.

2. Theoretical Framework

Before reviewing the literature on engineering ethics education and character formation, we want to clarify our terms and assumptions. We treat character and virtue as closely aligned: a person of excellent character is a virtuous person. Drawing broadly on Aristotelian ethics, we understand virtues as stable dispositions to think, feel, and act in morally good ways for morally good ends [1-4]. In practice, we often describe virtues to students and faculty as deep-seated habits of thought, emotion, and action that contribute to human flourishing.

Traditionally, virtues are defined such that they cannot be exercised for bad ends; fully manifesting a virtue necessarily entails acting rightly. Contemporary usage, however, often detaches virtue terms from this strict criterion. For example, a thief may be described as "patiently" waiting in an alley for his next victim, but such patience is not virtuous. Likewise, many traits—resilience, for instance—are not virtues in ordinary language because they can characterize actors pursuing immoral goals. Yet these traits can be construed as virtues when defined as dispositions that aim at good ends through morally appropriate means. This interpretive flexibility expands the range of traits that can be included within a virtue-based framework.

At Duke, we therefore adopt an ecumenical approach to which traits count as virtues, while still requiring that any trait be construed in a virtue-theoretic way. *Character Forward* uses a faculty-centered model for course integration: rather than prescribing a canonical virtue list at a school-level, we support faculty in identifying traits that meaningfully complement their courses and teaching goals. In EGR 101, this led us to focus on respect, curiosity, resilience, responsibility, and integrity—a set not drawn from any standard virtue list but selected because they were already naturally practiced by students in the phases of the design process that structured the course. In alignment with the name "Character Forward," we wanted to bring the traits already cultivated in this course *forward*—to make them explicit. These traits were identified over the course of several meetings with previous EGR 101 students, teaching assistants, and faculty.

We defined these traits as follows:

- **Respect** is a thoughtful awareness of and appreciation for others' identities, experiences, and needs.
- **Curiosity** is a habit of questioning and reflection that generates creative insights.
- **Resilience** is the ability to persist through setbacks and learn from failure.
- **Responsibility** is the courage to *own* our actions (and their consequences), to welcome accountability from others, and to follow through on our commitments.

- **Integrity** is a disposition to be honest, transparent, consistent, and authentic in every sphere of one's life.[1]

In taking an Aristotelian approach, we assume that these traits can be cultivated, chiefly through practice. We drew heavily on Lamb et al.'s seven strategies for virtue development [5], which informed the design of our interventions throughout the course. Briefly summarized, these strategies include:

1. **Habituation through practice**: building virtues through repeated, consistent practice, much like skill development.
2. **Reflection on personal experience**: reflecting on past experiences to understand successes, failures, and opportunities for improvement.
3. **Engagement with virtuous exemplars**: learning from peers or admired figures who model virtues in action.
4. **Dialogue that increases virtue literacy**: discussing the nature of virtues, their opposing vices, and their boundaries with related concepts.
5. **Awareness of situational variables**: recognizing how situational pressures and personal biases influence behavior.
6. **Moral reminders**: providing cues that reorient attention toward virtue goals.
7. **Friendships of mutual accountability**: forming supportive relationships that encourage virtuous behavior through honest feedback and shared practice.

A final assumption underlying our approach is that higher education institutions—especially those like Duke—have a mandate to form students of good character. Our university mission commits us to fostering students' "development as adults committed to high ethical standards and full participation as leaders in their communities" [6], and our engineering school endeavors to prepare students to "lead… ethical lives for the betterment of society" [7]. These commitments suggest that ethics education must extend beyond imparting theoretical knowledge or reasoning skills to include shaping students' dispositions, emotions, and actions in ways that promote flourishing.

Moreover, this emphasis on character comports with the goals of accrediting bodies like ABET. ABET's student outcome #4 requires that our students develop "[a]n ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" [8]. Although this ethics goal is narrower in scope than the comprehensive formation of students' character, this outcome is well served by developing students of good character. After all, a person of good character would be more likely to recognize and act on their ethical and professional responsibilities.

3. Literature Review

[1] You will notice that we called some of these traits "dispositions," others "habits," and yet others "abilities." These were definitions that we presented in class. Admittedly, we sacrificed some amount of philosophical precision to make them more colloquial.

This literature review examines existing work on engineering ethics education and character formation. We first summarize dominant models of ethics education in engineering and documented limitations. We then review emerging work that focuses on virtue ethics and character formation, highlighting how these approaches have been developed and implemented in engineering education contexts. Finally, we identify gaps in the literature that motivate this intervention.

Approaches to Engineering Ethics Education

Engineering ethics education has historically been grounded in professional responsibility, codes of ethics, and ethical decision-making frameworks. Early critiques noted a persistent tension between the technical core of engineering curricula and the perceived marginality of ethics instruction [9]. In response, educators have developed a range of instructional strategies, including standalone ethics courses, case-based discussions, and the integration of ethical reasoning into technical coursework.

One influential approach is what Davis calls "micro-insertion," which embeds brief ethics modules into technical courses to expose students to ethical issues without displacing technical content [10]. Case-based pedagogy has likewise been widely adopted as a means of engaging students in ethical analysis grounded in realistic engineering dilemmas [11]. Bairaktarova and Woodcock further argue that ethics instruction should be aligned with authentic engineering practice, noting mismatches between intended learning outcomes and students' lived experiences of engineering work [12].

While there have been large-scale reviews that begin to synthesize approaches to engineering ethics, there is notable discussion surrounding the scope of what ethics entails. Hess and Fore document a wide variety of ethics interventions in U.S. engineering programs but note that many focus narrowly on ethical reasoning or awareness [13]. Martin, Conlon, and Bowe similarly identify a dominance of individualistic and decontextualized approaches, calling for a shift toward socio-technical orientations that better reflect the realities of engineering practice [14]. Across this literature, scholars raise concerns that prevailing models often frame ethics as compliance with external rules or as episodic problem-solving, rather than as a constitutive element of professional identity [15].

While these approaches seem to increase ethical awareness and reasoning to some extent, they appear insufficient to bridge the gap between knowing what to do and actually doing it. Newberry and Schmidt both argue that this gap points to a deeper issue: traditional ethics education often neglects the formation of habits, motivations, and dispositions that shape how engineers behave in practice [9, 15]. These critiques have prompted calls to reconsider the goals of engineering ethics education and to explore pedagogies that engage students' character and identity as engineers.

Emerging Virtue Ethics and Character Formation in Engineering Education

In response to the limitations of rule- and dilemma-centered approaches, a growing body of scholarship has turned to virtue ethics and character education as promising frameworks for

engineering ethics education. Virtue-oriented approaches emphasize the formation of stable dispositions such as honesty, responsibility, and respect that enable engineers to act well across a wide range of situations, including those not easily anticipated by formal codes [11, 15].

Schmidt argues that virtue ethics offers a paradigm shift for engineering ethics education by reframing ethical practice from rule-following to a matter of character [15]. From this perspective, the central educational question becomes not merely what engineers should do in specific scenarios, but what kind of people engineers should become. Pierrakos et al. extend this argument by explicitly calling for a transition from ethics education to character education in engineering, suggesting that character formation better aligns with the profession's responsibility to society and with long-term ethical performance [16].

Several empirical and conceptual studies have begun to explore how virtue- and character-based frameworks can be operationalized in engineering education. Koehler et al. reviewed literature on four prominent virtues in engineering education, such as empathy and responsibility, finding that while these traits are frequently invoked as desirable outcomes, they are often underspecified and weakly connected to pedagogical practice [17]. Yeaman et al. similarly conducted a scoping review of character development pedagogies in engineering, identifying a diverse but fragmented set of interventions, ranging from reflective writing and service-learning to team-based activities and mentorship [18].

More recent work has focused on designing and assessing concrete instructional interventions aimed at cultivating specific virtues. Gross et al., for example, describe a course module designed to cultivate the "virtuous team worker," integrating teamwork activities with explicit discussion of virtues relevant to collaboration [19]. Their findings suggest that students can meaningfully engage with virtue language when it is clearly tied to their lived experiences in engineering courses. Mendonça, Dykhuis, and Lamb provide evidence from a course-based intervention demonstrating positive effects on students' character development, reinforcing the claim that higher education can intentionally cultivate virtues when interventions are structured and sustained [20].

Strategies for Cultivating Virtue

As mentioned above, Lamb and colleagues have synthesized work across several domains by identifying seven evidence-based strategies for cultivating virtue in university settings [5]. These strategies offer a practical bridge between virtue theory and educational design, and they have been increasingly cited in engineering education scholarship as a framework for intervention development [16, 19].

The emphasis on practice-based formation is consistent with broader research on professional identity development in engineering. Stevens et al. conceptualize engineering learning as a process of "becoming" an engineer, in which technical competence, professional identity, and values are co-constructed through participation in authentic engineering practices [21]. From this perspective, ethics and character are not add-ons to engineering education, but integral components of how students come to see themselves as engineers. Embedding virtue

cultivation within core activities such as design and teamwork thus aligns with established theories of engineering identity formation.

Reflection plays a particularly important role in translating experience into character development. Turns et al. argue that structured reflection supports deeper learning in engineering by helping students make sense of their experiences, connect practice to values, and develop professional judgment [22]. Within virtue-based frameworks, reflection serves not only a cognitive function but also a formative one, enabling students to recognize patterns in their behavior, identify obstacles to virtuous action, and articulate concrete strategies for growth.

From a philosophical standpoint, these pedagogical strategies are grounded in Aristotelian accounts of character formation, which emphasize habituation, practical wisdom, and the alignment of action with good ends. Kristjánsson articulates how contemporary character education draws on this tradition while remaining empirically informed, arguing that virtues are cultivated through sustained practice within supportive social contexts rather than through abstract moral instruction alone [23]. This account provides a theoretical foundation for integrating character education into engineering curricula in ways that are both philosophically robust and pedagogically actionable.

Taken together, this literature underscores that virtues are most effectively cultivated when they are embedded within authentic practices, supported by structured reflection, and reinforced through shared language and expectations.

Gaps in the Literature and Positioning of the Present Study

Although interest in virtue ethics and character education in engineering has grown, several gaps in the field of study remain. First, much of the existing literature is conceptual or exploratory, with relatively few empirical studies examining how virtue-based interventions function within required, large-enrollment engineering courses, particularly at the first-year level. Second, many interventions focus on a single virtue or a standalone module, rather than embedding multiple traits across the arc of the holistic engineering process.

Additionally, while scholars have called for integrating character education into engineering practice, there is limited work that systematically maps specific character traits onto distinct phases of the engineering design process. As a result, it remains unclear how students experience and interpret character formation when virtues are explicitly linked to the everyday practices that define engineering work.

The present study addresses these gaps by embedding structured character-focused interventions throughout a required first-year engineering design course. Drawing on a virtue-theoretic framework and evidence-based strategies for character cultivation, this work examines how students engage with multiple character traits as integral components of design practice. In doing so, it contributes empirical evidence to ongoing conversations about how engineering ethics education can move beyond compliance and reasoning toward the intentional formation of engineers of good character.

4. Methods

Description of the Course

EGR 101 *Introduction to Engineering Design and Communication* is a required course for all first-year engineering students at Duke. The central component of the course is a semester-long, real-world project proposed by a client external to the course. Students work in teams to fully understand the need, develop potential solution ideas, and iteratively prototype a selected solution. Throughout the course, students learn an engineering design process and apply that process to their specific project. They also gain technical skills (including CAD and 3D printing, circuits and Arduino, woodworking, and laser cutting), practice various forms of technical communication (written memos, oral presentations, and a poster presentation), and receive guidance regarding effective teamwork and project planning. By the end of the semester, students have generally developed and tested a physical prototype that aims to address the need initially presented by the client.

During the Fall semester, we have eight sections of EGR 101 with roughly 40-50 students and two instructors in each section. Project teams are typically made up of four students. Each section follows the same general structure, has the same assignments, and so on. However, sections do vary since each instructor approaches the course somewhat differently and each section has different projects. During roughly the first third of the course, teams are working to understand and analyze the problem and select a solution idea to move forward into prototyping. For the remainder of the course, teams are doing the hands-on work of prototyping and testing their idea.

Description of the Interventions

Three of the eight sections functioned as controls and were not altered to include any character formation strategies. Five of the eight sections were treatment sections. In those sections, we split the course into five phases and identified a key character trait that fit naturally with each phase. The phases and associated character traits are as follows:

- Phase 1: Team Formation (Respect)
- Phase 2: Ideation (Curiosity)
- Phase 3: Prototyping (Resilience)
- Phase 4: Testing (Responsibility)
- Phase 5: Sharing Results (Integrity)[2]

The following interventions were implemented in the treatment sections:

[2] Since EGR101 does not have problem sets and exams, many of the concerns regarding cheating that might exist in a traditional engineering course are not present. However, we have noticed that at the end of the semester, when students share the testing results for their prototypes, they indicate that their prototypes pass a surprisingly high percentage of their tests. We suspect there is some amount of deception going on in at least some groups, which is why we wanted to emphasize the importance of integrity in this final phase.

- On the first day of class, students were asked to provide a brief written response to the question "What does it take to be a good engineer?" Students briefly discussed their responses with classmates afterwards.
- At the beginning of each of the five phases of the course, a brief introduction to the relevant character trait was provided by the course instructors. Suggested content was provided to the instructors, but instructors were free to customize the content.
- The first slide for each lecture included a reminder of the relevant character trait for the then-current design phase at the top left-hand corner.
- At the end of each phase, students submitted a video reflection[3] on the relevant trait. For the first three phases, the video reflection was completed individually. For the last two phases, reflections were completed in project groups who then submitted a group video reflection. Below are the questions students were asked to reflect on:

    - Who is someone in your life (outside of this course) that exhibits this trait? What does that look like?
    - What is one time you've exhibited this trait? Where do you see opportunities to grow in this trait?
    - What do you think prevents people (possibly including yourself) from fully exhibiting this trait?
    - What practices, habits, or actions could help you or others grow in this trait?
    - Give a specific example of how you have observed this trait in one of your EGR101 classmates in the past few weeks.

Description of Assessment Tools

To examine the interventions' impacts, we adopted a pre/post design, collecting information from students in both the treatment and control sections both before and after they completed the course. There are few validated evaluation tools that capture the character-related information we were seeking.[4] After reviewing existing tools and tools used by other related initiatives at Duke, we developed specific questions relevant to our objectives. We used three sets of closed-ended 6-point agree/disagree Likert scales (ranging from "Strongly agree" to "Strongly disagree" and omitting a neutral middle option): (1) a 6-item set focused on character literacy and how students see character in relation to engineering, (2) a 10-item set focused on character self-reports, i.e., student beliefs about how they do or do not embody and employ key character traits, and (3) a 4-item set asking them about their perception of the course and its impact on them. Of these, students completed the "character literacy" and "self-report" sets both before and after the course, while the "impact" set was only completed at the conclusion of the course. For the wording of each set, see Tables 2, 3, and 4 in the following section as well as Appendix 1.

[3] Students had the option to submit written responses to the reflection questions, though the video was requested.
[4] We strongly considered using Furr and colleagues' Moral Character Questionnaire [23]. We also considered using the VIA-IS [24].

The post-course survey also included three open-ended items focused on the impact of the interventions and was only administered to students exposed to those interventions. Those items read as follows:

- In progressing through the 5 phases of EGR 101, you have received introductory content on key character traits at the beginning of each phase. In what ways has this introductory content impacted your experience of the course?
- In progressing through the 5 phases of EGR 101, you have completed various video or group reflections. Thinking about these reflections, in what ways have they impacted your experience of this course?
- Please provide any other thoughts you have on the character-related elements of this course. What worked well? What could be improved?

To assess the interventions' impact on students over the course of the semester, we compared students' pre and post answers to the closed-ended items, making it possible to examine how they changed over the semester. Then we compared the extent of change between control and treatment groups. We also reviewed treatment group student responses to the "impact" items asked at the end of the semester. Then we coded the answers to the open-ended items provided by treatment group students and examined the themes that we identified in these items. We used the reflections to compare treatment to control students and used treatment students' answers to the open-ended survey items to examine their perceptions of the impact the course interventions had on their understanding of ethics and character.

5. Results

A total of 239 students, 155 treated and 84 control, completed both pre- and post-course surveys and consented to their responses and course reflections being used in research. In the aggregated responses for each closed-ended item, changes between treatment and control groups were small and differences between the treatment and control groups did not approach statistical significance. Table 1 shows these differences for each group. We measured change as the individual student's post-course response to each survey item minus that student's pre-course response to that same item. Where appropriate, scale items were reverse coded so that for each scale item (and each aggregate scale) positive change reflects the desired direction.

Table 1:
Within-student Change in Overall Metrics

	Overall Character Literacy	Overall Traits
Control	0.30	0.12
Treatment	0.24	0.13

As Table 1 shows, changes for both groups were positive, but modest. The small size of the change reflects at least in part the fact that students generally rated themselves highly at the beginning of the semester, so had limited room for improvement. On the pre-course survey, the average control student rated themself at 4.7 for the Character Literacy scale, while treatment group students rated themselves at 4.6; similarly, on Traits, students rated themselves at 5.0 for

control and 4.9 for treatment. We also note that particularly for excellent students who are aware of their self-presentation, self ratings such as these may also reflect high self-confidence or a desire to look good.

Only two items in either of the two item sets showed a change of more than half a unit over the course of the semester, and differences between control and treated students, again, did not approach statistical significance. The two largest differences were on (1) students' self-reported ability to "name several character traits that are important for engineers to develop," at 0.86 for treated students and 0.75 for control students, and (2) students' self-report on being "acutely aware of my character strengths and weaknesses," where treated students improved 0.50 and control students 0.69. The item-level differences for the Character and Traits scales appear in Tables 2 and 3, respectively.

Table 2
Within-student Change in Character Literacy Metrics, by Item

To what extent do you agree or disagree with the following statements:	Control	Treatment
I can name several character traits that are important for engineers to develop.	0.75	0.86
I'm acutely aware of my character strengths and weaknesses.	0.69	0.50
I believe being a person of good character is essential to being an excellent engineer.	0.23	0.25
Strong technical skills are sufficient for success in engineering.	0.02	0.07
I see engineering work as connected to broader social and ethical responsibilities.	0.23	0.12
I rarely think about how my behavior affects my work with others.	0.08	0.24

Table 3
Within-student Change in Trait Metrics, by Item

Being honest with myself, I can say that I have a habit of ...	Control	Treatment
seeking to understand the perspectives of others.	0.39	0.28
treating others in ways that make them feel heard and respected.	0.04	0.04
asking questions that deepen my understanding.	0.11	0.20
approaching unfamiliar challenges with a genuine desire to learn.	0.07	0.06
giving up easily when I face setbacks.	0.19	0.01
viewing mistakes as opportunities for learning.	0.24	0.19
taking ownership of my work and its impact on others.	0.18	0.24
following through on my commitments, even when tasks are difficult or uninteresting.	0.21	0.17
being honest with others about important or difficult matters.	0.13	0.06
making decisions that align with my values, even when shortcuts are available.	0.04	0.01

At the end of the semester we asked all students for their views about their learning over the course of the semester. We compared responses on 4 items asking students generally about their experiences in their engineering courses. Overall, students rated their learning on personal growth and character positively, though interestingly, control students consistently rated their learning slightly higher than did treatment students, with differences that approach statistical significance on a couple of items: whether the courses have "helped me to see character traits as important to engineering ($p < .08$), and whether the courses have "helped me cultivate my own character" ($p < .10$). Learning explicitly about a given topic can diminish learners' confidence that they understand it well or are mastering it, which may explain why control students

expressed more confidence in their abilities and the impact of engineering courses on these items [26]. The results for each group, by item, appear in Table 4.

Table 4
Average Value By Course Impact Item for Control and Treatment Group Students

	Control	Treatment
In my [engineering] courses this semester, I was challenged to grow personally, not just technically.	5.04	4.97
Compared to other courses I have taken, my [engineering] courses this semester have helped me to see character traits as important to engineering.	5.26	5.05
Compared to other courses I have taken, my [engineering] courses this semester helped me cultivate my own character.	5.06	4.80
My [engineering] courses this semester have improved my ability to recognize and name character traits or virtues that are important to engineering.	5.27	5.12

Although the closed-ended items seem to suggest little impact of our interventions, the open-ended survey items present a very different picture. A total of 162 treated students who completed the post-course survey provided answers to these questions and consented to have their responses used in research, and the vast majority of them – 145, or 90% – provided positive comments about the ways in which the course impacted either or both of their understanding of and actions regarding the key character traits the class covered. Some mentioned using what they learned in the class to think about qualities they want to develop or reduce, with one student commenting that the course,

> "…has given me the space to take the time to reflect upon both the actions of myself and my team to identify traits and behaviors I want to continue or adopt, and other traits and behaviors I want to reduce or avoid."

Another student noted that the course allowed them to,

> "… test my character, especially in a team setting, and [I] realized that I must change some things in order to improve."

Several students spoke positively about the way the character elements of the course shaped the value they derived from it or from college more generally. One noted,

> "I found myself being more fulfilled, not just intellectually by the course, but also emotionally. I felt like there was more purpose behind the course than just completing a project. Growth as an individual was just as important."

Another student wrote,

> "It's made me feel like the course (and the school as a whole) cares about more than just the work we do and the grades we get."

Students also noted that the skills they learned are transferable or broadly applicable, providing comments such as,

- "[The assignments we completed are] reflections of myself and comments for other people. Improvements are not only for being an engineer but also for being a human being,"
- "The character-trait introductions at the start of each phase helped me see the purpose behind the work, connecting our technical tasks to real professional skills like communication, resilience, and collaboration. They made the course feel more intentional and helped me grow not just as an engineer, but as a teammate and problem-solver throughout our design process."
- "Instead of just allowing me to finish my EGR 101 project, I think it achieved its goal of preparing me to start any venture, whether … in engineering specifically or any other industry. I think that's why my experience of the course was very positive, because it taught me transferable skills."

Not all students' comments were positive: 13 students (8%) made negative remarks about the character elements of the course not adding value or being busywork. A typical remark in this category came from a student who said,

> "They seemed more like busy work than something I saw value in doing and it felt like it was disconnected from the engineering class."

Other students spoke in mixed terms about the character components, identifying positive aspects but complaining that they took too much time away from other elements of the course, or, conversely, that not enough time was devoted to the character components to make them meaningful. A few commented that the character components were relevant but, for these students, did not introduce concepts or skills they had not already mastered. Other students had detailed recommendations regarding ways to retool the reflection assignments or expressed preferences for one type of reflection over another – such as preferring written reflection to video reflections, or individual reflections to group reflections, or vice-versa.

6. Discussion

Overall, the findings reflect positively on the interventions while underscoring persistent challenges in measurement. The open-ended responses indicate that many students, when prompted, recognized the value of character to engineering practice and experienced the character-focused components of the course as meaningful. Students frequently described increased reflection on their habits, values, and team dynamics, and several emphasized that the interventions gave the course a sense of purpose beyond technical achievement alone. In contrast, the closed-ended survey items produced results that were ambiguous and, in some cases, counterintuitive. For example, students in the control group reported greater agreement than treatment students with the statement, "I'm acutely aware of my character strengths and weaknesses," despite the fact that only treatment students completed regular reflections on their own character. This pattern suggests limitations in what the closed-ended items were actually measuring.

Two related issues likely contributed to these results. First, the pre- and post-course surveys exhibited strong ceiling effects: students entered the course already rating themselves highly (nearly 5 out of 6) on most items, leaving little room for measurable growth. Ceiling effects are known to constrain variance and reduce sensitivity to change [27]. Second, these ceiling effects are compounded by response biases that are especially pronounced for morally valenced items. Social desirability bias and self-enhancement bias lead respondents to over-report positive traits and to view themselves as morally better than average [28–29]. Alicke's classic study illustrates this effect: college students consistently rated themselves above average on positive traits, particularly moral ones, despite the statistical impossibility of such distributions [30]. When survey items implicitly ask respondents to acknowledge moral deficiency, many are unwilling to do so. Importantly, these dynamics complicate interpretation of change over time. From a virtue-theoretic perspective, increased self-awareness or humility may lead students to judge themselves more critically, resulting in flat or even declining self-reports despite genuine character development. In this sense, self-report measures may obscure rather than reveal growth.

Instructor-level variation further complicates interpretation. Some control-section instructors were already engaged in programming with *Character Forward* and may have implicitly reinforced character-related themes, while some treatment-section instructors expressed hesitance with the emphasis on character. These contextual differences likely influenced how interventions were enacted and perceived by students.

Taken together, these findings suggest that self-report measures of character—especially those framed in morally evaluative terms—are poorly suited to detecting change. Even character literacy items are likely compromised when disagreement can carry negative moral implications or appear to be socially undesirable. Alternative approaches merit consideration, including forced-choice items that require respondents to choose between competing positive options, and proxy measures that assess features of the learning environment (like whether the institution values character development or whether its instructors model or support character development) rather than students' own character.[5] The closed-ended item that came closest to being a proxy measure in this sense was the item "I can name several character traits that are important for engineers to develop" because agreement or disagreement with the statement does not seem to directly implicate one's own character. And, as it turns out, this was the only close-ended item that revealed a statistically significant trend in the desired direction.

For the present study, qualitative data appear to offer the most reliable evidence of impact. Students' reflections provided concrete examples, self-critique, and behavioral intentions that are not easily explained by response bias alone, and the frank, informal tone in which many are written suggests to us that with these replies students are genuinely sharing their views and perspective rather than trying to look good or give the 'right' answer. While qualitative methods have limitations, they may be the better current option for assessing character development in the engineering classroom.

Finally, the interventions themselves invite refinement. Reflection prompts could be made more specific to each trait, reducing repetitiveness and increasing depth. We will also

[5] We are grateful to Jesse Pappas for these suggestions.

consider adding a trait-specific activities to the course to address the expressed desire to have the traits more fully integrated into the course.

7. Conclusion

In this study, we integrated character interventions into a large, required, first-year engineering design course at Duke. Five character traits—respect, curiosity, resilience, responsibility, and integrity—were mapped onto five phases of the course and reinforced through brief instruction, moral reminders, and structured reflection. Our goal was to examine how our interventions impacted students' self-perceived character, beliefs about character, and understanding of what it means to be a good engineer.

Our findings suggest that students valued the character interventions and saw them as important parts of their engineering education. Qualitative data indicate that many students experienced the interventions as contributing to their personal growth. At the same time, this study highlights the difficulty of measuring character development through self-report and character literacy instruments. Ceiling effects and well-documented response biases limit the interpretability of morally valenced survey items. In this context, qualitative evidence and indirect proxy measures may offer more reliable insight than direct self-assessment of character traits.

More broadly, this work supports ongoing calls to move engineering ethics education beyond compliance and theory toward pedagogies that intentionally cultivate character through practice. While further refinement and longitudinal study are needed, this intervention suggests ways that first-year engineering courses can play a meaningful role in forming engineers who are both morally and technically sound.

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Appendix 1
Closed-ended Survey Items Asked of Students in EGR 101

Character Literacy (asked pre and post)
To what extent do you agree or disagree with the following statements: (6 point agree/disagree scale)

1. I can name several character traits that are important for engineers to develop.
2. I'm acutely aware of my character strengths and weaknesses.
3. I believe being a person of good character is essential to being an excellent engineer.
4. Strong technical skills are sufficient for success in engineering.
5. I see engineering work as connected to broader social and ethical responsibilities.
6. I rarely think about how my behavior affects my work with others.

Traits (asked pre and post)
Being honest with myself, I can say that I have a habit of ... (6 point agree/disagree scale)

1. seeking to understand the perspectives of others.
2. treating others in ways that make them feel heard and respected.
3. asking questions that deepen my understanding.
4. approaching unfamiliar challenges with a genuine desire to learn.
5. giving up easily when I face setbacks.
6. viewing mistakes as opportunities for learning.
7. taking ownership of my work and its impact on others.
8. following through on my commitments, even when tasks are difficult or uninteresting.
9. being honest with others about important or difficult matters.
10. making decisions that align with my values, even when shortcuts are available.

Impact of Character Forward (post only)
Thinking about EGR 101 and EGR 105 (if you are currently taking EGR 105),[6] how much do you agree or disagree with the following statements: (6 point agree/disagree scale)

1. In my [engineering school] courses this semester, I was challenged to grow personally, not just technically.
2. Compared to other courses I have taken, my [engineering school] courses this semester have helped me to see character traits as important to engineering.
3. Compared to other courses I have taken, my [engineering school] courses this semester helped me cultivate my own character.
4. My [engineering school] courses this semester have improved my ability to recognize and name character traits or virtues that are important to engineering.

[6] All first-year students take EGR 101; a subset also take EGR 105. We introduced character formation practices into both courses in different ways. To reduce over-surveying, we opted to use a single post-program survey administered in EGR 101 to ask these closed-ended items, and we phrased the questions to incorporate experiences in both courses, if applicable. We were able to delineate between students who were in treatment sections of both 101 and 105, students who took only one or the other, and students who took neither.