Cultivating Resilience and Collaboration in a Foundational Computing Course

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Abstract: This article presents an evidence-based intervention integrating character formation into *Computing for Engineers*, a required first-year course at Duke University. Traditionally centered on programming and computational thinking, the course is now intentionally designed to cultivate resilience and collaboration through partnership with the Pratt School of Engineering's ethics initiative, *Character Forward*. Drawing on Crossan and colleagues' Leader Character Framework and strategies from Lamb and colleagues, students develop virtue literacy through lecture, case examples, and reflections that connect character to engineering practice. Reflection prompts and team charters encourage students to recognize resilience in debugging and iteration, and to define norms for effective teamwork and feedback. A mixed-methods assessment using pre-/post-course surveys measured changes in students' understanding and self-reported growth. While our closed-ended measures revealed little growth, our open-ended measures found that over 80% of student respondents reflected positively on how the interventions impacted their resilience and collaboration. Ultimately, embedding virtue-focused pedagogy in this foundational computing course models how engineering education can unite technical proficiency with the habits of character essential for responsible and effective professional practice.

1. Introduction

Engineering education has traditionally emphasized mastery of technical knowledge and analytical problem-solving. While these competences remain essential, they are not sufficient for engineering excellence. Today, the professional landscape is marked by rapid technological change, global interdependence, and complex social interactions —conditions that demand not only technical proficiency, but also personal qualities that enable engineers to persist through failure, work productively with others, and exercise sound judgment under pressure. We asked ourselves, what kind of people are we preparing students to become?

This question is particularly pressing in the context of uncertainty. Today's first-year students will someday use technologies to design, regulate, or manage that do not currently exist. Similarly, the ethical, organizational, and interpersonal challenges they will face cannot be fully anticipated. While ethical frameworks and decision-making tools are valuable, on their own they seem insufficient to prepare students for the unpredictable social and technological environment graduates will face decades from now.

Research and everyday experience suggest that failure in professional conduct often arises not from a lack of ethical knowledge but from poorly formed habits —like the inability to persevere through setbacks, to listen carefully to collaborators, or to engage constructively with disagreement [1]. These capacities can be understood as elements of character. Traits such as resilience and collaboration shape how engineers respond to failure, distribute responsibility, and sustain effort within teams. Without an emphasis on such traits, students may take away the message that engineering excellence is primarily an individual, technical achievement, instead of a shared, morally significant practice.

In response to these concerns, we incorporated character formation into EGR 105L *Computing for Engineers*, a first-year engineering course that introduces students to solving problems with computing. Rather than treating character as an abstract or auxiliary topic, we embedded focused reflection and practice on resilience and collaboration directly into the course's structure. These traits were selected because they are foundational to the engineering design process. Resilience supports learning through iteration and failure, while collaboration enables students to integrate diverse perspectives and work effectively toward shared goals.

Through targeted instruction, guided reflection, and team-based activities in labs and projects, the course aims to help students recognize these two traits as not merely desirable soft skills, but as core dimensions of engineering competence. This paper presents the rationale for this approach, describes its implementation, and examines the impact that character education had in first-year students.

2. Theoretical Framework

Drawing broadly on Aristotelian virtue ethics, we understand character traits as stable dispositions of thought, feeling, and action that orient agents toward human flourishing [2-4]. While many taxonomies of character traits are available, we drew on Mary Crossan and colleagues' Leader Character Framework [5].[1] Crossan and colleagues identify multiple dimensions of character, each composed of specific character elements. Rather than introducing entirely new traits into the curriculum, we examined which traits were already being implicitly cultivated in the course and made these traits explicit objects of pedagogical attention. This approach aligns with *Character Forward*'s guiding assumption that character formation is always occurring, intentional or not; and one task of educators is to render this formation visible and subject to deliberate pedagogical design.[2]

In Crossan et al.'s framework, resilience is an element within the broader character dimension of courage. They describe resilience as the capacity to endure difficult conditions and to recover effectively from setbacks [5, p. 143]. Collaboration, by contrast, is treated as a full character dimension composed of several elements, including cooperativeness, collegiality, open-mindedness, flexibility, and interconnectedness [5, pp. 55-66].

Consistent with traditional Aristotelianism, our approach assumes that character traits can be cultivated. We draw heavily on Lamb and colleagues' account of virtue development, particularly their emphasis on practice and reflection as central mechanisms of character formation [6]. They identify several pedagogical strategies that support virtue development, five of which we share here:

1. **Habituation through Practice.** Practice is necessary to internalize virtues and make them part of one's character. Just like skills used in any enterprise, such as engineering or sports, a virtue can become a disposition and habit through repeated practice.
2. **Dialogue that Increases Virtue Literacy.** Gaining a conceptual and practical understanding of what the virtue is, which vices oppose it, and how it might differ

[1] The Jubilee Centre offers another popular framework [6].
[2] *Character Forward* is an ethics initiative in Duke's Pratt School of Engineering.

from other related concepts can help one act more appropriately in relevant circumstances. Dialogue that promotes virtue literacy can aid this conceptual understanding, which in turn can equip students to recognize when and how the exercise of specific virtues is required.

3. **Reflection on Personal Experience.** Reflecting on experience can help students use their own lives as case studies to better understand moments where they acted well, so they can repeat such behavior, or times they could have acted differently, so they discern what they need to change to act better in the future.
4. **Engagement with Virtuous Exemplars.** Central to character education are exemplars and role models who embody the virtues in daily life. Exemplars help illustrate the virtues and inspire others to work harder to improve their character, providing concrete models to emulate and guidance on how one can act in a given situation. Exemplars do not need to be moral heroes to be effective. Indeed, some research shows that peer exemplars can even be more effective and attainable role models than distant heroes. Fellow students, for example, can be exemplars to each other by modeling patience, respect, and teamwork.
5. **Friendships of Mutual Accountability**. Lastly, moral development is not something people can do alone. Good friendships are also important in cultivating virtue. Friends can embody specific values and virtues and help model good character. They can help each other develop wisdom and determine which choices are better than others. They can also help each other see themselves differently, hold each other accountable to their deepest values and commitments, and present opportunities to practice virtues, such as generosity, empathy, and kindness, to another in a supportive context. Friendships provide valuable support and accountability in a moral life. [3]

Our research presupposes that institutions of higher education like Duke bear responsibility for the moral formation of their students. Duke's mission explicitly commits it to fostering ethical agency and leadership, and our engineering school's mission statement stipulates that we will prepare our students to live ethical lives for the betterment of society. These institutional commitments suggest that ethics education cannot be limited to the cultivation of ethical reasoning skills alone but must also attend to the formation of students' dispositions, affective orientations, and patterns of action. Nor is it sufficient for higher education to focus exclusively on technical knowledge and skill. This limitation is especially salient in the age of artificial intelligence, an age in which technical competencies and knowledge may depreciate as AI become more competent. By contrast, traits such as resilience and collaboration are likely to remain central to responsible professional practice in uncertain and evolving contexts.

Finally, this approach aligns well with ABET accreditation criteria [9]. Although character traits are most naturally mapped onto Student Outcome 4, which concerns ethical and professional responsibilities, cultivating resilience and collaboration also supports Outcomes 5 and 7 [10]. Student Outcome 5 emphasizes the ability to function effectively on a team whose members provide leadership, create a collaborative environment, establish goals, plan tasks, and meet objectives—capacities that directly depend on collaborative character. Student Outcome 7

[3] Quoted and paraphrased from "The Virtues of Teamwork," Gross et al. [8]; expounded in "How is Virtue Cultivated?" Lamb et al. [7].

emphasizes the ability to acquire and apply new knowledge as needed using appropriate learning strategies, a process that frequently requires resilience.

3. Literature Review

Engineering ethics education has historically emphasized professional responsibility, codes of ethics, and ethical decision-making frameworks [11–13]. Instructional strategies such as standalone ethics courses, case-based discussions, and the integration of ethics modules into technical courses are now common. While these approaches have been shown to increase ethical awareness and reasoning, multiple reviews note persistent limitations. Ethics is often treated as episodic problem-solving or rule compliance rather than as a constitutive dimension of professional identity and everyday engineering work [14, 15]. This can make ethics feel disconnected from the practice of engineering and a gap remains between students' ability to reason about ethical dilemmas and their capacity to *act* ethically in practice. This gap suggests that prevailing approaches attend insufficiently to the habits, motivations, and dispositions that shape how engineers perceive situations, deliberate, and act over time [11, 16]. As a result, several scholars have called for a reorientation of ethics education toward forms of professional formation that more directly engage character and identity [16, 17].

In response to these concerns, a growing body of scholarship has turned to virtue ethics and character education as promising frameworks for engineering ethics education [16, 17]. Virtue-oriented approaches shift the focus from isolated decisions to the cultivation of stable dispositions that enable engineers to act well across a wide range of contexts, including those not anticipated by formal codes. From this perspective, the central educational question becomes not only what engineers ought to do, but what kind of people engineers ought to become.
Recent conceptual and empirical work has begun to examine how character-based frameworks can be operationalized in engineering education. Reviews of the literature note that while virtues are frequently invoked as desired outcomes, they are often underspecified and weakly connected to concrete pedagogical practices [18, 19]. Scoping reviews of character development initiatives reveal a diverse but fragmented landscape of interventions, including reflective writing, service-learning, mentoring, and team-based activities [19]. Together, this work underscores both growing interest in character formation and the need for interventions that are systematically embedded within core engineering practices.

More focused course-level studies suggest that students can meaningfully engage with virtue terminology when it is explicitly connected to their lived experiences in engineering classrooms. Interventions that integrate virtue concepts into teamwork and project-based learning show that students are better able to articulate norms of good practice and reflect on their own development when character is made an explicit object of attention rather than an implicit byproduct of instruction [20, 21].

Within this emerging literature, resilience and collaboration have been identified as traits of particular importance for contemporary engineering practice. Calls from professional bodies emphasize that future engineers must be adaptable, resilient, and capable of effective collaboration in the face of uncertainty, complexity, and rapid technological change [9, 21]. Teamwork, which is closely related to collaboration, has been a point of common emphasis in

engineering curricula [18]. Studies of engineering practice further indicate that teamwork and interpersonal competencies are among the abilities engineers themselves report as most important in their professional work [22]. Resilience is likewise closely aligned with the iterative, uncertain, and failure-prone nature of engineering work. Research on engineering learning suggests that students' early encounters with challenge and iteration are formative for learning trajectories and professional identity, particularly in first-year coursework [23].

Despite growing recognition of the importance of resilience and collaboration, relatively little work has examined how these traits can be intentionally cultivated within required, large-enrollment first-year engineering courses. Existing interventions often focus on a single virtue or a standalone module rather than embedding multiple traits across the arc of a course.

The present study addresses these gaps by embedding structured, character interventions aimed at cultivating resilience and collaboration throughout a foundational computing course for engineers. By integrating character-focused pedagogy into core technical activities, this work contributes empirical evidence to ongoing conversations about how engineering ethics education can move beyond ethical reasoning and compliance toward the intentional formation of engineers into people who are habitually resilient and collaborative.

4. Methods

Computing for Engineers is an introductory computing course for engineers with an emphasis on computational thinking and project-based learning. In this course, students engage in a collaborative project to use computing to solve an authentic engineering problem. Collaboration is framed as a skill required for engineering practice and as a key aspect of good character.

The course-level learning objectives include:

- Manage complex problems by using abstraction and problem decomposition.
- Generalize patterns in data and processes to devise an algorithm.
- Read and write Python code with essential programming constructs and data structures.
- Comprehensively test and systematically debug code.
- Develop proficiency with professional tools and practices for collaborative work, including version control and documentation.
- Model and visualize numeric, textual, image, or audio data.
- Cultivate self-sufficiency seeking new information and resilience dealing with technical challenges.
- Practice effective collaboration, managing group dynamics, leveraging the strengths of individual team members, and learning from different perspectives.

Students engage in a semester-long collaborative project that has scaffolded milestones that align with the programming concepts students are learning. Each milestone is attempted over the course of a "sprint" run with the Agile Scrum approach [24], a project management framework that promotes fast failure and iteration, enabling teams to quickly respond to feedback.

The project, labs, and quizzes use specifications grading. This grading method involves providing students with a detailed list of specifications for each assignment and grading each submission holistically as either “meets expectations“ or “needs revisions.“ Opportunities for revision are built into the course so that students can move from “needing revisions” to “meeting expectations.” This framework allows students to build resilience by giving them a structured opportunity to practice overcoming failure.

This course had five lecture sections, three of which applied character interventions (the treatment sections), and two of which did not (the control sections). The specific interventions included (1) an overarching introduction to character as part of the course introduction and motivation early in the semester, (2) student input on what makes for a great teammate with peer evaluation at specific project milestones, and (3) structured reflections on resilience in hands-on laboratory activities.

As part of the first lecture in the course, character was highlighted in the women “computers” who engineered the 1960’s ENIAC missile guidance systems in the early days of computing. The collaboration intervention was based on the one described by Gross et al. in “The Virtues of Teamwork.” [8] In the class period when the project was introduced, students were polled and asked, “What makes someone a great collaborator?” Students then sorted these responses into a Venn diagram of “Respecting all team members,” “Integrating the team’s goals,” and “Appropriately contributing.” These responses were discussed as a class and compiled. Students named thirteen attributes which, at four later points in the semester, they were asked to reflect upon, both in regard to themselves and to give feedback to their teammates. The class-compiled attributes are listed below:

1. Listens well to others
2. Is honest and transparent
3. Cares about teammates
4. Communicates clearly and kindly
5. Disagrees productively
6. Gives constructive criticism
7. Is punctual
8. Contributes their fair share of quality work
9. Works hard
10. Stays on task
11. Acquires needed domain knowledge
12. Is reliable
13. Is organized

In addition, the character trait of resilience was emphasized early on during the first hands-on laboratory activity. Resilience was distinguished from perseverance: resilience being the ability to overcome or “bounce back” following a setback and perseverance being continued effort or working at something until you get it. Resilience was then emphasized during the course through reflection activities following in-class laboratories where failure points and the need to

overcome them were expected. Three overarching questions related to resilience were used to frame these reflections:

1. What was your initial reaction when something did not work?
2. What question(s) came to your mind?
3. What different, more informed forward-step did you take?

Subsequently, each lab submission included four to six reflection questions. Below are examples of the questions that were focused on resilience:

- (Lab 1) Where did you or your group get stuck in identifying or describing the algorithm?
- (Lab 1) What revisions did you make to your algorithm after receiving your partner group's feedback?
- (Lab 2) If you got stuck, where did you get stuck, and how did you get through it?
- (Lab 3) Describe an instance when using github did not work as you expected. What did you need to move forward? Where did you look? Did you ask anyone for help?
- (Lab 3) Describe a problem that you found in your code during development. How did you solve that problem?
- (Lab 4) What challenges did you encounter in this lab?
- (Lab 5) What challenges did you overcome? Discuss what the challenge was, how it related to your task, and how you approached it.
- (Lab 6) What did you find difficult about working with code that was drafted by GenAI?

To examine the interventions' impacts, we administered surveys collecting information from students in both the treatment and control sections before and after they completed the course. Because *Character Forward* is relatively new and without a precise parallel elsewhere, we examined related internal programs to identify possible evaluation tools, adapting and adopting those best suited to measuring the resilience and collaboration we sought to foster.[4] We employed two self-report items focused on resilience – asking students to answer using a 6-point agree/disagree Likert scale as follows,

Being honest with myself, I can say that I have a habit of ...

1. Giving up easily when I face setbacks.
2. Viewing mistakes as opportunities for learning.

We also used six self-report items focused on collaboration, asking students to place themselves on a 6-point agree/disagree Likert scale when considering the statement, "I rarely think about how my behavior affects my work with others," and using the same scale for the following items

Being honest with myself, I can say that I have a habit of ...

[4] Validated assessment tools like the Moral Character Questionnaire [25] and the VIA-IS [26] were considered.

1. Seeking to understand the perspectives of others.
2. Treating others in ways that make them feel heard and respected.
3. Taking ownership of my work and its impact on others.
4. Following through on my commitments, even when tasks are difficult or uninteresting.
5. Being honest with others about important or difficult matters.

In the post-survey we included four closed-ended items asking students about their perception of the course and its impact on them (shown in Table 3 below). The post-course survey also included the following three open-ended items, administered only to students exposed to the interventions:

- In progressing through the course, you have received content or engaged in activities aimed at cultivating your resilience. How has this impacted you?
- In progressing through the course, you have received content or engaged in activities aimed at helping you become a more collaborative person. How has this impacted you?
- 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 we examined the closed-ended items used pre and post to compare the change over the semester between the treatment and control groups and reviewed treatment student responses to the closed-ended "impact" items. We coded and analyzed students' answers to the open-ended survey items to understand how they perceived the course's impact on their character.

5. Results

A total of 139 students, 84 treated and 55 control, completed both the pre- and post-course surveys and consented to their responses and course reflections being used in research. The difference between treatment and control groups on closed-ended character self-report measures revealed little change – either substantive or statistical – over the course of the semester. Table 1 shows the two items measuring resilience and shows the differences for each group, measured as the individual student's response to each item on the post-course survey minus their response to each item on the pre-program survey (so, it shows their change over the course of the semester). Neither shows a change of more than a quarter of a unit over the course of the semester for either group, and group differences do not approach statistical significance. Because the first item is negative – measuring an undesired behavior – a decrease over the course of the semester reflects improvement, and for this item we do see greater improvement for the treatment than the control group, though as noted not a statistically significant difference. For the second item, positive change reflects improvement and here, the control group shows slightly greater improvement than the treatment group.

Table 1
Within-student Change in Resilience Metrics

	Control	Treatment
I have a habit of giving up easily when I face setbacks.	0.18	-0.10
I have a habit of viewing mistakes as opportunities for learning.	0.24	0.10

Turning to students' self-reports of their collaborative skills and behaviors, again the extent of change is small for all items and both groups. Only on one item is there statistically significant change between the two groups: control students reported improvement on "following through on commitments" at 0.42 units, whereas treatment group students reported at the end of the semester that they were 0.04 units *less* likely to exhibit this trait than they were at the beginning of the semester – a difference that is statistically significant at the 0.01 level. Indeed, with the exception of the first item, "I rarely think about how my behavior affects my work with others," control students consistently reported greater improvement in their collaborative skills than treatment students.

Table 2
Within-student Change in Collaboration Metrics

	Control	Treatment
I rarely think about how my behavior affects my work with others.	0.35	0.08
I have a habit of seeking to understand the perspectives of others.	0.27	0.21
I have a habit of treating others in ways that make them feel heard and respected.	0.00	0.00
I have a habit of taking ownership of my work and its impact on others.	0.29	0.11
I have a habit of following through on my commitments, even when tasks are difficult or uninteresting.	0.42	-0.04
being honest with others about important or difficult matters	0.09	-0.01

In addition to examining change over the course of the semester, at the end of the semester we asked students their views about their learning over the course of the semester. We compared responses between treatment and control students on 4 items asking students generally about their experiences in the engineering school. Overall, students rated their learning on personal growth and character positively, with treated students consistently rating their learning slightly higher than did control students – though the differences only approach statistical significance on one item: whether their engineering courses challenged them to grow "personally, not just technically" ($p < 0.08$). Table 3 presents the results for each group, by item.

Table 3
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.	4.76	5.11
Compared to other courses I have taken, my [engineering] courses this semester have helped me to see character traits as important to engineering.	5.09	5.24
Compared to other courses I have taken, my [engineering] courses this semester helped me cultivate my own character.	4.84	4.98
My [engineering] courses this semester have improved my ability to recognize and name character traits or virtues that are important to engineering.	5.09	5.24

While the closed-ended survey items do not suggest that our interventions had a significant impact, the open-ended survey items offer a different picture. 64 treated students who completed the post-course survey provided answers to the open-ended questions and consented to have their responses used in research. Almost all these students – 54 students, or 84% of the respondents – commented favorably on the ways in which the course and its interventions shaped their resilience. One noted that it was beneficial to receive content aimed at cultivating resilience before they had to exercise resilience because it made "[them] aware of the skill [they] were developing." Another highlighted strategies they learned to navigate difficulties: "I have become more resilient in my approach to programming. I have also learned how to find help well either from a TA, through office hours, or online, all of which have allowed me to persevere with a problem for longer." Another said, "It helped me see making mistakes as an opportunity to learn and try again."

Students were similarly positive about the course's impact on their abilities to collaborate, with 52 students (81% of respondents) commenting positively on the way the course impacted them. One explained how it expanded their learning: "I thought coding would be fairly independent, however I have worked a lot with others throughout this course. I learned a lot from my peers as we would tackle problems differently and would learn from them because we took different approaches." Another provided a somewhat self-deprecating answer that still emphasized the positive ways in which working with classmates improved their learning, saying, "I relied heavily on my classmates who were better at computing than me. I learned how to collaborate with them to get help without simply asking for the answers so that there was still a layer of learning that I had to do. I also learned how to be a better team player on assignments where I certainly was not going to be the leader." Another student contrasted their college experience with their high school experience, saying, "I have definitely become a more collaborative person. In high school I would have done everything by myself. Now I realize I need a team." Yet another commented on the ways in which the course's focus on collaboration helped them connect with peers and develop soft skills that will be valuable in their profession, saying "Working with others on the main project not only helped me to better know my peers and form connections within [the engineering school], but also helped me to see the value of task delegation and collaboration in a real engineering context."

Students also described skills they acquired, either explicitly or implicitly, as transferable or broadly applicable, with comments such as,

- "I have learned how to communicate effectively and resolve conflicts with group members."
- "It made me more aware of others' backgrounds and abilities."
- "I think that engagement in collaboration has made me more positive because I really struggle in this course but being able to work with people has made me approach ... problems with a better attitude."
- "Building my resilience has been really helpful because it taught me to not give up when something didn't work at the start and to truly understand what I did wrong before I tried fixing the mistake/issue. I can take this skill and apply it to other areas of my life because it is an extremely useful and versatile skill."

Not all students' comments were positive: 4 students (6% of respondents) made negative remarks about the resilience elements of the course. They remarked that the character components were either not comprehensive enough or felt like "busywork" – for example, one student commented that, "I don't think this needs to be the focus of this class." Twice as many students – 8, or 13% – made negative comments about the course's collaborative components. One focused on the difficulty they experienced mastering the course material and wrote, "I wouldn't really call it collaboration ... I've improved my ability to struggle with others," while another said, "those who are already good collaborators weren't benefitted and those who weren't, didn't become any better."

6. Discussion

A central question raised by these findings is why students' self-reported character traits remained largely unchanged between the treatment and control groups—and in some cases appeared to improve more in the control group—while students in the treatment sections reported slight changes in the course impact measures while also offering strongly positive qualitative feedback on the interventions. At first glance, this pattern is counterintuitive. One would expect, for example, that the group of students who report that they developed "a habit of following through on [their] commitments, even when tasks are difficult or uninteresting," would also tend to report that the course "challenged them to grow personally, not just technically." We see the opposite here and this confusion is compounded by the positive qualitative feedback: students describe positive effects on their character, yet this improvement is not reflected in the close-ended items.

There are several plausible explanations. One draws on the Dunning–Kruger effect, a well-established cognitive bias whereby individuals with limited understanding in a domain tend to overestimate their competence, while those with greater understanding become more critical of their own abilities [27]. In this context, students who had not previously reflected on their collaborative or resilient dispositions may have entered the course with comparatively inflated self-assessments. Students in the treatment sections were then repeatedly invited to examine what resilience and collaboration require in practice. Increased conceptual clarity and self-

awareness may therefore have led some students to assess themselves more modestly by the end of the semester. On this interpretation, stable or even declining self-reports do not indicate a lack of character development but may actually reflect growth.

Several additional factors further complicate interpretation of the closed-ended survey results. First, the measures exhibited strong ceiling effects: students entered the course already rating themselves highly on most character-related items, leaving little room for detectable improvement [28]. Second, these ceiling effects are likely amplified by response biases that are particularly pronounced for morally valenced traits. Social desirability bias and self-enhancement bias are known for inclining respondents to present themselves in a favorable light, often rating themselves above average on positive characteristics, especially moral ones [29–31]. When survey items implicitly invite students to acknowledge moral shortcomings, it is likely that many are understandably reluctant to do so, limiting the sensitivity of self-report instruments to change over time.

These dynamics suggest that Likert-style character self-report measures may be poorly suited for capturing short-term changes in character within educational contexts. By contrast, the open-ended responses provide a more textured account of impact. The responses from treatment group students articulated specific strategies for persisting through failure, navigating collaboration, and transferring these habits beyond the course—evidence of metacognitive engagement that is itself relevant to character formation.

These findings suggest several implications for future work. Qualitative methods appear especially well-suited for assessing character interventions. If closed-ended measures are used, they may be more informative when framed to assess students' perceptions of their educational environments rather than their own moral self-concepts. This is because a low rating in this framing would not implicate *the student* as failing in some way but someone or something else. Notably, one survey item that approached statistical significance in the desired direction asked whether students' engineering courses challenged them to grow personally, not just technically. This item invites evaluation of *the course* rather than *the self*, avoiding the implication that the student has not lived up to some standard.[5]

One final item to note is that the course structure for all students was, to some extent, already designed to promote resilience and collaboration; however, the treatment group had additional explicit instruction on these traits. Some of the data may reflect that the control version of the course already contained some amount of latent character education.

7. Conclusion

We take the view that cultivating engineers of good character is an important function of undergraduate engineering education. In contrast to programs that focus on ethics as a set of rule-based professional principles, our approach is to cultivate character traits as a stable dispositions

[5] Another promising mode of assessment would focus on concrete behaviors: Did student projects in the treatment sections turn earn higher grades than the control sections? Did the treatment course have higher retention rates? Did the treatment sections have fewer instances of teamwork issues raised to instructors? We were not set up to assess these questions, but they are nonetheless worth exploring in future research.

that one can develop through practice. This approach is well-suited to an environment of technological uncertainty. Our interventions sought to embed character formation and practice into the curriculum at an impactful moment, so that students habituate themselves to acting well in the first year and continue practicing throughout their career.

This work demonstrates both the promise and the challenges of intentionally integrating character formation into a foundational engineering course. Embedding explicit attention to resilience and collaboration within the core technical practices of a first-year computing course proved feasible and, by students' own accounts, meaningful. Although the closed-ended self-report measures showed little difference between treatment and control groups, qualitative data suggest that students in the treatment sections developed awareness of the demands of resilience and collaboration, articulated sophisticated understandings of what these traits entail, and identified concrete strategies for applying them. Taken together, these findings suggest that character interventions may exert their strongest effects not through rapid shifts in self-perception, but through increased moral attention, metacognition, and interpretive skill. Future research should continue to refine assessment strategies for character development and explore how sustained, program-level interventions might support deeper and more visible forms of growth over time.

References

[1] Treviño, Linda K, Gary R Weaver, and Scott J Reynolds. "Behavioral Ethics in Organizations: A Review." *Journal of Management* 32.6 (2006): 951-990. Web.
[2] Aristotle, Nicomachean Ethics. 2nd Ed. Indianapolis, IN: Hackett Publishing Company, 1999.
[3] J. Annas, Intelligent Virtue. New York, NY: Oxford University Press, 2011. C. Miller, The Character Gap: How Good Are We? New York, NY: Oxford University Press, 2018.
[4] L. T. Zagzebski, Virtues of the Mind: An Inquiry into the Nature of Virtue and the Ethical Foundations of Knowledge. Cambridge, UK: Cambridge University Press, 1996.
[5] M. Crossan, J. Gandz, G. Seijts, and G. Reno, *Developing Leader Character*. New York, NY, USA: Routledge, 2017.
[6] Jubilee Centre for Character and Virtues, "Frameworks for character education," *Jubilee Centre for Character and Virtues*, Univ. of Birmingham. [Online]. Available: https://www.jubileecentre.ac.uk/character-education-/frameworks/.
[7] Michael Lamb et al., "How Is Virtue Cultivated? Seven Strategies for Cultivating Virtue in the University," *Journal of Character Education* 17, no. 1 (2021).
[8] M. D. Gross, J. Wiinikka-Lydon, M. Lamb, O. Pierrakos, and A. Yeaman, "The Virtues of Teamwork: A Course Module to Cultivate the Virtuous Team Worker," in *2021 ASEE Virtual Annual Conference Content Access*, Virtual Conference, Jul. 2021.
[9] Accreditation Board for Engineering and Technology (ABET), *Criteria for Accrediting Engineering Programs, 2025–2026*. Baltimore, MD, USA. [Online]. Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2025-2026/.
[10] J. Koehler, O. Pierrakos, and A. Yeaman, "Character Development in the Engineering Classroom: An Exploratory, Mixed-Methods Investigation of Student Perspectives on Cultivating

Character," in *2023 ASEE Annual Conference & Exposition*, Baltimore, MD, USA, Jun. 2023, Paper no. 10.18260/1-2-43174
[11] B. Newberry, "The dilemma of ethics in engineering education," *Science and Engineering Ethics*, vol. 10, no. 2, pp. 343–351, 2004, doi: 10.1007/s11948-004-0030-8.
[12] M. Davis, "Integrating ethics into technical courses: Micro-insertion," *Science and Engineering Ethics*, vol. 12, pp. 717–730, 2006.
[13] C. E. Harris, "The good engineer: Giving virtue its due in engineering ethics," *Science and Engineering Ethics*, vol. 14, pp. 153–164, 2008.
[14] J. L. Hess and G. Fore, "A systematic literature review of U.S. engineering ethics interventions," *Science and Engineering Ethics*, vol. 24, pp. 551–583, 2018.
[15] D. A. Martin, E. Conlon, and B. Bowe, "A multi-level review of engineering ethics education: Towards a socio-technical orientation of engineering education for ethics," *Science and Engineering Ethics*, vol. 27, no. 5, Art. no. 60, 2021, doi: 10.1007/s11948-021-00333-6.
[16] J. A. Schmidt, "Changing the paradigm for engineering ethics," *Science and Engineering Ethics*, vol. 20, no. 4, pp. 985–1010, 2014.
[17] O. Pierrakos, M. Prentice, C. Silverglate, M. Lamb, A. Demaske, and R. Smout, "Reimagining engineering ethics: From ethics education to character education," in *Proc. IEEE Frontiers in Education Conf. (FIE)*, 2019, pp. 1–9.
[18] J. Koehler, O. Pierrakos, M. Lamb, *et al.*, "What can we learn from character education? A literature review of four prominent virtues in engineering education," in *2020 ASEE Virtual Annual Conf. Content Access*, 2020.
[19] A. Yeaman, J. Koehler, J. Pappas, and O. Pierrakos, "Scoping review of character development pedagogies in engineering education," in *Proc. IEEE Frontiers in Education Conf. (FIE)*, 2022, pp. 1–12.
[20] M. D. Gross, J. Wiinikka-Lydon, M. Lamb, O. Pierrakos, and A. Yeaman, "The virtues of teamwork: A course module to cultivate the virtuous team worker," in *2021 ASEE Virtual Annual Conf. Content Access*, 2021.
[21] National Academy of Engineering, *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC, USA: National Academies Press, 2004.
[22] H. J. Passow, "Which ABET competencies do engineering graduates find most important in their work?" *Journal of Engineering Education*, vol. 101, no. 1, pp. 95–118, 2012. [20] S. E. Mendonça, E. M. Dykhuis, and M. Lamb, "Purposeful change: The positive effects of a course-based intervention on character," *The Journal of Positive Psychology*, vol. 19, no. 2, pp. 323–336, 2024, doi: 10.1080/17439760.2023.2178954.
[23] R. Stevens, K. O'Connor, L. Garrison, C. Jocuns, and D. Amos, "Becoming an engineer: Toward a three-dimensional view of engineering learning," *Journal of Engineering Education*, vol. 97, no. 3, pp. 355–368, 2008.
[24] Nilson, L.B. (2014). Specifications Grading: Restoring Rigor, Motivating Students, and Saving Faculty Time (1st ed.). Routledge. https://doi.org/10.4324/9781003447061
[25] R. M. Furr, M. Prentice, A. H. Parham, and E. Jayawickreme, "Development and validation of the Moral Character Questionnaire," *J. Res. Pers.*, vol. 98, p. 104228, Jun. 2022. doi: 10.1016/j.jrp.2022.104228.
[26] VIA Institute on Character, "VIA Inventory of Strengths (VIA-IS)," accessed Jan. 2026. [Online]. Available: https://www.viacharacter.org

[27] J. Kruger and D. Dunning, “Unskilled and unaware of it: How difficulties in recognizing one’s own incompetence lead to inflated self-assessments,” *Journal of Personality and Social Psychology*, vol. 77, no. 6, pp. 1121–1134, Dec. 1999.
[28] S. Y. Chyung, D. Hutchinson, and J. A. Shamsy, “Evidence-based survey design: Ceiling effects associated with response scales,” *Performance Improvement*, vol. 59, no. 6, pp. 6–13, Jun. 2020.
[29] D. S. Weiner and C. L. Guenther, “Self-Enhancement Bias,” in *Encyclopedia of Personality and Individual Differences*, V. Zeigler-Hill and T. K. Shackelford, Eds. Cham, Switzerland: Springer, 2018, pp. 1–7.
[30] D. L. Paulhus and D. B. Reid, “Enhancement and denial in socially desirable responding,” *Journal of Personality and Social Psychology*, vol. 60, no. 2, pp. 307–317, 1991, doi: 10.1037/0022-3514.60.2.307.
[31] Alicke, M. D. (1985). Global self-evaluation as determined by the desirability and controllability of trait adjectives. *Journal of Personality and Social Psychology, 49*(6), 1621–1630