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Character Development in the Engineering Classroom: An Exploratory, Mixed-Methods Investigation of Student Perspectives on Cultivating Character

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I. Introduction

Ethics education is an undisputedly essential part of engineering education. Society, industry, universities, and accreditation demand that engineering students be better educated to handle the many ethical situations that professional practice will require of our graduates. While engineering educators continue to explore how to most effectively prepare students for complex and nuanced ethical decision-making in their professional careers [1] – [8], traditional approaches to engineering ethics education have been largely limited to ethical reasoning guided by one correct answer situations, code or compliance-based ethical cases [4], [9]. Such approaches are important but not adequate enough to prepare students for the myriad of ethical complexities they will face on a daily basis in the practice of engineering. [4], [9] – [12].

In recent years, a character-based (also referred to as virtue-based or character strengths-based) approach to engineering ethics education has been proposed [4] and is being implemented as a promising solution to the shortcomings of engineering ethics [3], [20]. A character education approach to engineering ethics fosters greater comfort with ambiguity and the nuances of everyday ethics. Furthermore, a character education approach offers personal motivation and actionable dimensions to ethical reasoning [14], [15].

Incorporating character education into engineering education does, however, bring its own challenges. Engineering faculty report that they lack the confidence, knowledge, and time to design and implement character education in their classrooms [16] – [18]. Some argue that putting the onus of engineers' ethical development on individual engineering faculty is arguably unfair and unrealistic [19]. The relatively few character interventions in engineering education that do exist are fairly robust, reinforcing the assumption that it does indeed require significant time, effort, and knowledge from engineering faculty [3], [20] – [21]. Additionally, research indicates that undergraduate engineering students are not very receptive to ethics education upon entering college [13], and their valuation of how important engineering ethics is to practice decreases during their four years of schooling [5], further indicating that traditional approaches to engineering ethics education fall short.

Given the evidence of student disengagement in engineering ethics, and the barriers to faculty implementation of character education, this study sought to explore the perspectives of undergraduate engineering students who had experienced intentionally designed character education interventions in their engineering courses to determine what course elements were most engaging and effective in their self-reported character growth. The following research questions guided this study:

1. Which character strengths / virtues did students perceive to have strengthened across the engineering curriculum and in specific engineering courses?
2. Which classroom experiences (i.e., activities, pedagogies, or practices) did students attribute to their perceived character growth?

Results provide insight into how to foster effective student engagement in character education through accessible instructional approaches that are viable even when faculty time, confidence, or other resources may be lacking.

II. Virtues, Character, and Engineering Education

Rethinking engineering ethics education to include a character virtue ethics approach is intended to transcend the limitations of compliance-based, deontological ethics, and utilitarian ethics approaches [4]. Virtue ethics emphasizes the virtues of character that promote the flourishing of individuals and communities [22] – [24] through the cultivation of dispositions to act, think, and feel in ways that enable us to do the right thing [25] – [28].

One prominent virtue ethics framework used to connect virtue ethics to professional education is the Jubilee Centre Framework [6], [15]. While there are other relevant virtue ethics frameworks, such as the Virtues in Action (VIA) approach [29], we appreciated the categorizations of the Jubilee Centre Framework which divides virtues into four categories: performance, intellectual, moral, and civic. All of these virtues culminate into one integrated virtue - practical wisdom. This virtue facilitates discerning, deliberative action in situations where other virtues collide is in essence, ethical decision-making. Figure 1 serves to depict the four virtue categories and the critical role of practical wisdom.

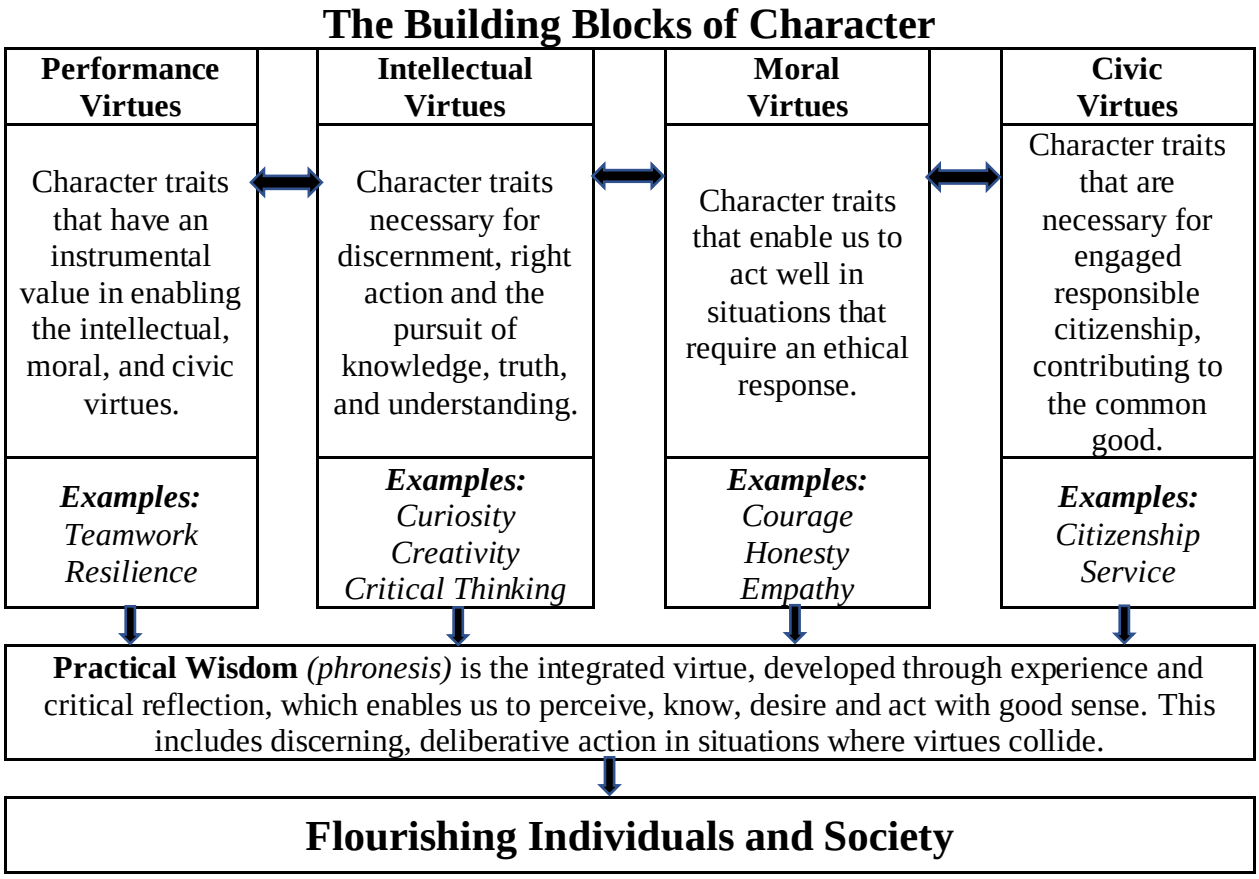

Figure 1: Adapted from The Jubilee Framework of the Building Blocks of Character [15].

In the context of engineering education, a few publications have previously leveraged the Jubilee Framework [3], [4], [30] – [31]. These character virtues can be mapped to the seven ABET student outcomes further clarifying their applicability in engineering (Table 1). Multiple virtues may map to multiple ABET outcomes and there is room for interpretation. We do not claim that this mapping is complete, but a start. For example, complex technical problem-solving (SO1) requires critical thinking, and at times, creativity. The design process (SO2) may also involve creativity and critical thinking and also empathy when considering the needs of all stakeholders.

Table 1: Character Virtues mapped to ABET Student Outcomes

ABET Student Outcome (SO)	**Relevant Virtues**
SO1: an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	Creativity, Critical Thinking
SO2: an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.	Creativity, Critical Thinking, Empathy, Justice
SO3: an ability to communicate effectively with a range of audiences	Honesty, Courage, Creativity
SO4: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	Purpose, Service, Justice, Honesty, Courage, Practical Wisdom
SO5: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.	Teamwork, Empathy, Honesty, Courage
SO6: an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.	Critical Thinking, Honesty
SO7: an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.	Resilience, Creativity, Curiosity, Purpose, Service

While a range of virtue development enhances all seven student outcomes independently, Figure 2 illustrates the theoretical framing for how collectively these virtues lay the foundation for *Practical Wisdom* needed in ethical decision making (SO4). Developing practical wisdom, arguably the end goal of character education, in theory should result in more nuanced ethical decision-making in support of human flourishing and in the face of complex obstacles.

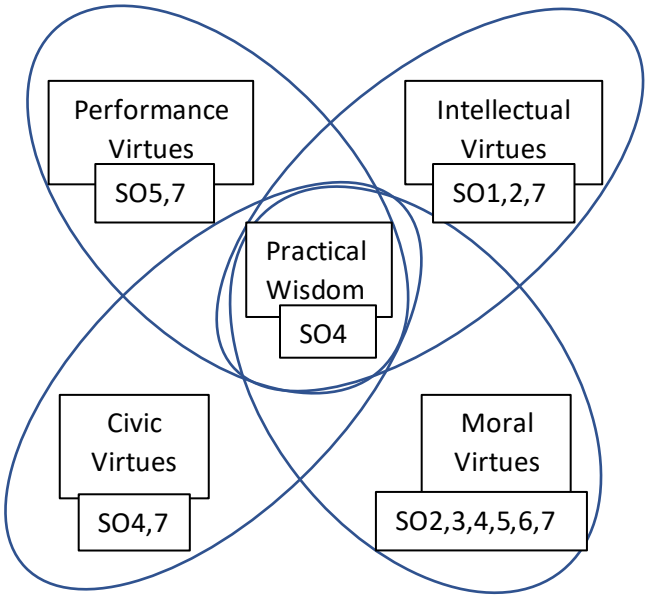

Figure 2: Framework connecting character virtues to ethical decision-making in engineering

III. Study Context

In 2017, Wake Forest University (WFU) launched its newest undergraduate program, a Department of Engineering targeted at offering an interdisciplinary BS Engineering degree. Delivery of the curriculum was happening in the midst of developing the program and vision, and it became clear that this was an opportunity to reimagine and redefine engineering education and engineering graduates. Virtues like *empathy, courage, intellectual humility, integrity, self-awareness, justice, purpose, curiosity, creativity, compassion and authenticity* were identified as being essential to the kind of engineering graduate desired. The students themselves were committed to the university motto of Pro Humanitate (For Humanity) and they too desired to redefine engineering education and became partners in the building of the new WFU Engineering Department.

Wake Forest University was already the university home to many character education scholars – Christian Miller, Eranda Jayawickreme, Michael Furr, William Fleeson, and Michael Lamb [28, 33-36]. In 2018, a university wide initiative launched to institutionalize character education across undergraduate education and professional education. The Program for Leadership and Character (PLC) became the academic home for many university efforts related to character education.

Founding Engineering Chair (Olga Pierrakos and co-author) connected with the soon-to-be PLC Executive Director (Michael Lamb) and shared the engineering team's visioning documents. This new collaboration made visible the connections between these two new efforts – a brand-new Engineering Department and a brand-new Program for Leadership and Character. With

Kern Family Foundation (KFF) funding, stemming from WFU Engineering joining the Kern Engineering Education Network (KEEN), WFU Engineering embarked on a partnership with the PLC that continues today. The KFF KEEN award aligned with the department's vision to "**Educate the Whole Engineer For Humanity".** The KFF KEEN award targeted the integration of engineering fundamentals, character education, and entrepreneurial education. Intentionality around providing engineering faculty autonomy and faculty development resulted in hiring several character education postdoctoral fellows. Engineering faculty (permanent, visiting, and part-time) along with these postdoctoral fellows worked to incorporate over 14 virtues infused across 12 engineering courses in the curriculum. The faculty team experimented with diverse pedagogical approaches and strategies. Buy-in and having nearly 100% of faculty (permanent, visiting, and part-time) participate in bridging engineering education with character education has achieved essential learning for us as a team. During the 2022-2023 academic years, the research team focused on assessing student insights, perspectives, and learning as a result of the many character-based interventions across the curriculum. This paper serves as one example of sharing student perspectives that continue to inform the project. Student perspectives guide us in improving the integration of character education within engineering education. Key facets that are essential to this integration are the project-based learning environment that cuts across the curriculum from year one to year four and other innovative pedagogies (e.g., use of mastery-based learning approaches, flipped classrooms environments, case-based learning, and collaborative learning).

Table 2 presents some of the engineering courses and their associated primary virtues targeted. Courses with targeted virtues means that engineering faculty took intentional steps to introduce and talk about the virtue(s) in the context of the course or specific course activities. The degree of exposure for each virtue and in each course varied. It is beyond the scope of this paper to describe in detail the modules of each course. Relevant publications are cited for the modules that have been published [37] – [40]. Please note that the terms character virtues and character strengths are used interchangeably in this paper.

Table 2: WFU Engineering Required Courses and targeted character virtues/strengths.

Course Name	**Virtues Targeted**
EGR 111 - Intro to Engineering Design	Overview of virtues
EGR 112 – Intro to Engineering Experimentation	Teamwork
EGR 211 – Materials and Mechanics	N/A
EGR 212 – Transport Phenomena	Resilience
EGR 311 – Controls and Instrumentation	Creativity, Curiosity, Intellectual Humility
EGR 312 – Computational Modeling	Practical Wisdom, Intellectual Humility, Curiosity, Creativity
EGR 313 – Capstone Design I	Purpose
EGR 315 – Capstone Design II	Empathy, Courage, Teamwork

IV. Methods

The original rationale for this study was to gather student feedback for internal learning and continuous improvement, such as to inform curricular and pedagogical revisions. This was important because we observed a lack of student engagement with the explicitly developed character modules, consistent with the studies reporting lack of engineering student engagement with ethics education [5], [13]. Concurrently, there was anecdotal evidence emerging that students were reporting positive ethics and character learning from classroom experiences that were not intentionally designed as such.

Education research shows student perspectives and feedback lead to significant contributions and insights that faculty can use to improve student motivation and engagement [41]. While there are limitations to self-reporting as the sole source of determining student engagement [41], [42], this study was intended to be an exploratory investigation to inform curricular improvements and students' overall perceptions of character education. Again, the focus of this study is not to rigorously study character growth but rather explore evidence of student engagement, and the limitations of self-reporting to measure change in character are well documented [43].

Survey data for this study was collected in May 2022 from seven of the required engineering courses that were taught in the Spring 2022 semester. A total of 161 student responses were collected representing nearly all enrolled students. The first survey question asked students to select which character strengths from a predetermined list (*creativity, curiosity, critical thinking, service, empathy, courage, resilience, honesty, justice, purpose, teamwork, intellectual humility*, and *practical wisdom*) they felt that the course helped them to develop. The thirteen virtues on the list were selected to reflect which virtues the faculty had identified as valuable and covered a breadth across all four Jubilee Centre framework categories. These targeted virtues are not the only ones important to engineers and engineering professional practice but were reflective of the faculty discussions thus far. The virtue definitions provided to students in the survey were adapted and simplified from psychology and philosophy literature as well as the Jubilee and VIA frameworks [15], [29] (Table 3). The survey answer choices included "yes", "no" and "unsure." This question was then followed by optional open-response prompts for each character strength asking which aspects of the course facilitated their growth in that character strength.

Table 3: Virtues and definitions we adopted for this study.

Targeted Virtues	Jubilee Framework	Definitions We Adopted For this Study
Teamwork	Performance Virtue	Being collaborative and participative as a group or team member
Resilience	Performance Virtue	The capacity to recover quickly from difficulties
Creativity	Intellectual Virtue	Thinking of unique ways to solve problems and create new opportunities or products
Curiosity	Intellectual Virtue	Being interested in new ideas, experiences, and people
Intellectual Humility	Intellectual Virtue	Having an accurate understanding and acceptance of one's own intellectual strengths and limitations
Critical Thinking	Intellectual Virtue	Being analytical and approaching challenges from multiple perspectives
Purpose	Civic Virtue	Having a sense of meaning beyond oneself
Service	Civic Virtue	Working to benefit others
Justice	Civic Virtue	Valuing and working for fairness and equality
Empathy	Moral Virtue	Putting oneself in other people's shoes and understanding other points of view
Honesty	Moral Virtue	Telling the truth
Courage	Moral Virtue	Being willing to engage challenges that are difficult or dangerous
Practical Wisdom	Integrated Virtue	Knowing what the good, right, or best thing is to do given a particular set of circumstances

Pertinent to the first research question was determining which character strengths or virtues students perceived to have strengthened across all seven engineering courses. Data analysis involved reviewing student responses to the first survey question and summing the total counts per virtue. The percentage of students' reporting growth was calculated across all student responses. Note that students were invited to respond to growth across all 13 identified virtues and not just the virtues that were targeted for each course. Virtue results were categorized into four tiers:

(1) **Tier 1 Virtues (Very Highly Endorsed)** – endorsed by 70% or more of the students,

(2) **Tier 2 Virtues (Highly Endorsed)** – endorsed by 60% to 69% of the students,

(3) **Tier 3 Virtues (Moderately Endorsed)** – endorsed by 50% to 59% of the students, and

(4) **Tier 4 Virtues (Marginally Endorsed)** – endorsed by less than 50% of the students.

Pertinent to the second research question was determining which classroom experiences students attributed to their perceived character growth. The open-response questions were analyzed using a grounded theory inductive approach to determine emergent themes given the exploratory nature of this study [44]. There were two criteria considered when determining themes. Either (1) the same or similar student response was reported across multiple courses, or (2) the same or similar response was provided by multiple students in a single course. Given the open-ended nature of the survey design, unclear student responses were excluded from the themes. These themes were determined by a single researcher and are meant to be regarded as initial hypothesis generating results that will warrant further, more rigorous methodological study.

V. Results

This section shares findings that answer the two research questions. The first research question showcases students' perceived character strength gains across the core required engineering courses in the curriculum and within each of these courses. Findings for the second research question present the varied classroom pedagogies that students attributed to their character growth. Many of these pedagogies are accessible and could be easily implemented by engineering faculty who do not have training in character development.

Research Question 1 – Students' Perceived Character/Virtue Growth in the Classroom

Figure 3 shows a ranking of the virtues across all core engineering courses as determined by the percentage of students who endorsed that virtue.

> **Tier 1 Virtues:** Five out of the thirteen virtues were very highly endorsed by a strong majority of the students (70% or greater) – *teamwork, critical thinking, resilience, creativity,* and *curiosity*. Interestingly, two of these highly endorsed virtues are performance virtues (*teamwork* and *resilience*) and three are intellectual virtues (*curiosity, critical thinking* and *creativity).* Many engineering educators would argue that these highly endorsed virtues are inherently present in most engineering curricula and the undergraduate engineering experience, as well as inherently linked to ABET Student Outcomes. We would agree.
>
> **Tier 2 Virtues:** Two out of the thirteen virtues were highly endorsed by a solid majority of the students (60% to 69%) – *intellectual humility* and *practical wisdom*. The former is an intellectual virtue, and the latter is the integrated virtue.
>
> **Tier 3 Virtues** Four out of the thirteen virtues were moderately endorsed by 50% to 60% of the engineering students – *purpose, honesty, courage*, and *empathy*. Tier 3 virtues start to tap moral virtues (*honesty, courage, and empathy*) and one civic virtue (*purpose*).
>
> **Tier 4 Virtues:** Two out of the thirteen virtues were marginally endorsed by less than 50% of the students – *justice* and *service*.

Such results are not surprising given the nature of engineering practice and engineering education where the need to perform and understand engineering knowledge are top priorities.

Thus, we might expect that performance and intellectual virtues would inherently be more strongly endorsed by the engineering students. This is not unique to Engineering, however. The Jubilee Framework (Figure 1) even defines performance virtues as "Character traits that have an instrumental value in enabling the intellectual, moral, and civic virtues" [15]. Once competence in performance virtues is gained, then moral and civic virtues can become more prominent.

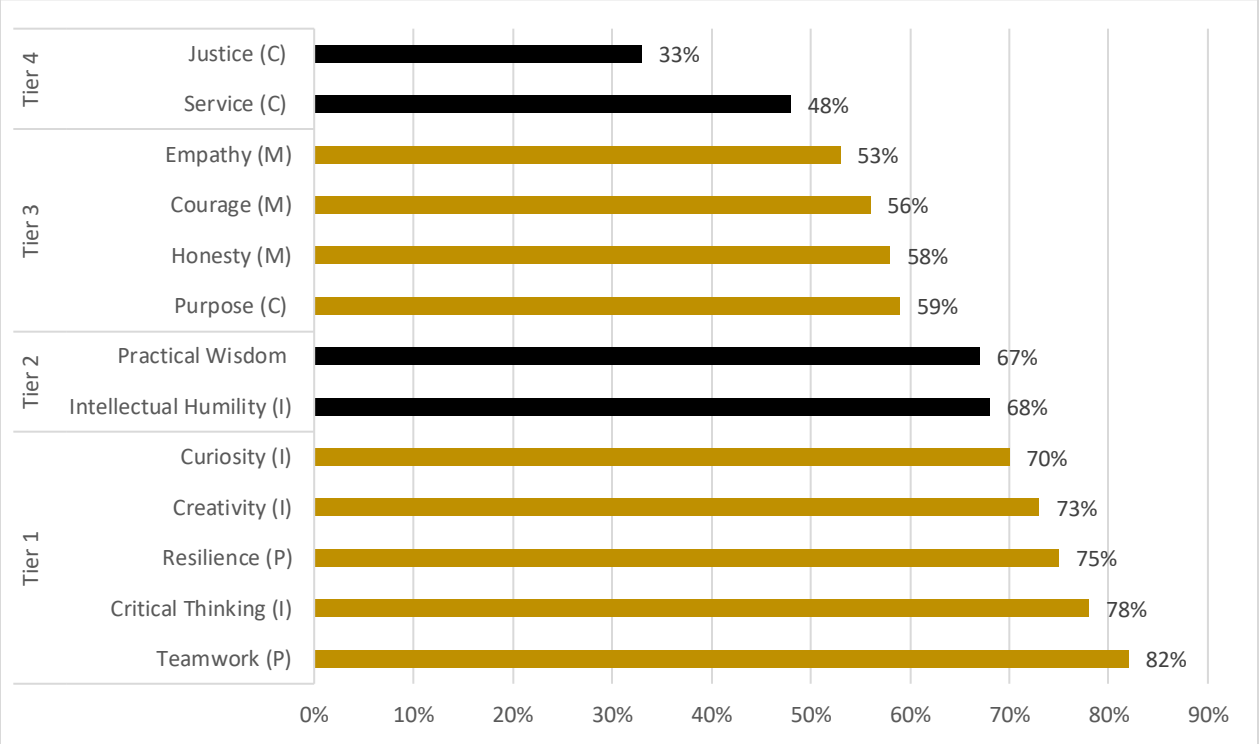

***Figure 3**:* Percentage of engineering students who noted character virtue growth across the eight core engineering courses. The designation in the parentheses serves as a label for the Jubilee Framework category: (P) Performance Virtue, (I) Intellectual Virtue, (M) Moral Virtue, (C) Civic Virtue.

Table 4 shows the top endorsed virtues (Tier 1 virtues) per core engineering course. Virtues that had been intentionally targeted by course character modules are in bold. It is compelling to note that while these targeted virtues are among the most highly endorsed virtues in four of the seven courses, there are many other non-targeted virtues that are also included in this top tier indicating that students perceive virtue growth even when it is not a targeted virtue.

Findings once again reveal that performance virtues (*teamwork* and *resilience*) and intellectual virtues (*creativity*, *critical thinking*, *curiosity*, and *intellectual humility*) are highly evident to the students in their engineering courses. It is important to note that students identified *critical thinking* as a virtue embedded in all courses. To varying degrees, they also identified *creativity*, *curiosity*, and *intellectual humility*. The top moral virtues were *honesty*, *courage*, and *empathy* but limited to a few courses, and the only highly endorsed civic virtue was *purpose*, identified in just two of the core engineering courses.

Table 4: Top endorsed virtues at the course level and organized by the Jubilee Framework categories of performance virtues, intellectual virtues, civic virtues, and moral virtues.

Course Name	Very Highly Endorsed (Tier 1 – 70% of students or higher)				
	Performance Virtues	**Intellectual Virtues**	**Moral Virtues**	**Civic Virtues**	**Integrated Virtue**
Intro to Eng. Design (1st Year)	Teamwork Resilience	Critical Thinking Creativity Curiosity			
Intro to Eng. Experimentation (1st Year)	**Teamwork** Resilience	Critical Thinking Creativity Curiosity			
Materials & Mechanics (2nd Year)	Teamwork Resilience	Critical Thinking Creativity Intellectual Humility	Honesty Courage	Purpose	Practical Wisdom
Transport Phenomena (2nd Year)	Teamwork **Resilience**	Critical Thinking Curiosity Intellectual Humility	Honesty Courage Empathy		Practical Wisdom
Controls & Instrumentation (3rd Year)	Teamwork Resilience	**Critical Thinking** **Creativity** **Curiosity** Intellectual Humility			
Computational Modeling (3rd Year)	Teamwork Resilience	**Critical Thinking** **Curiosity** Intellectual Humility			Practical Wisdom
Capstone Design (4th Year)	Teamwork Resilience	Critical Thinking Creativity Curiosity Intellectual Humility	Honesty	Purpose	Practical Wisdom

Research Question 2 – Classroom Experiences that Students Attributed to Their Perceived Character Growth and Virtue Gains

As noted in the results for research question 1, it is evident that students attributed their character growth to a broad range of course experiences that extended beyond intentionally designed character modules. This section presents the top two to three course experiences per virtue that students identified in supporting their character growth across all course pedagogies grouped by type of virtue (performance, intellectual, moral, civic, and integrated) in Tables 5-9 respectively.

According to students, performance virtues are most supported by participating in group work and challenging course material. Intellectual virtue growth is most supported by open-ended problems and projects and engaging lecturers/instructors. Both performance and intellectual virtue growth were supported by mastery-based learning pedagogies and peer/instructor

feedback. Moral virtue growth was due to wide-ranging experiences including self-directed learning opportunities, facing challenging communication scenarios, instructor role-modeling, and personal reflection. Civic virtue growth is linked to connecting course content to real-world applications and working indirectly or directly with a variety of stakeholders. Growth in *practical wisdom*, the integrated virtue, in addition to being indirectly supported by all other virtue growth was directly connected to opportunities to be in a decision-making position coupled with exposure to real-world applications and time for reflection. The breadth of these results reveals that there are many accessible approaches to incorporating character education in engineering that are engaging and impactful to students.

Table 5: Top 2-3 course experiences related to each performance virtue growth

Performance Virtues	Course Experiences Students Associated with Performance Virtue Growth
Teamwork	1. Participating in ***group work*** like projects. 2. Working on longer term ***projects*** and being forced to ***confront challenges together in a team setting***. 3. ***Peer team-member reviews*** and learning how to ***evaluate the effectiveness of teamwork***.
Resilience	1. A ***mastery-based learning approach*** to teaching where students are supported to try, fail, get feedback, and resubmit assignments towards mastery. 2. ***Facing difficulty*** with course content and coursework. 3. ***Overcoming unexpected problems and challenges*** in ***projects*** and ***labs***.

Not surprisingly, ***teamwork*** growth is most supported by having ample time spent doing collaborative group work, but the impact is enhanced when they are primed on how to recognize qualities of effective teams, are with the same team members over time so they are forced to face obstacles together, and there are explicit activities for self and peer reflection to facilitate overcoming those obstacles. The student quote below, from the senior year capstone design course sequence, serves to illustrate this finding:

> *"The entire year was spent working with a small group of individuals. In this time, we learned various strategies about how to work effectively with one another while also maintaining fairness and accountability." – 4th Year Student*

Students reported the most growth in ***resilience*** when faced with challenging coursework or project obstacles and having the opportunity to fail and try again (i.e. a mastery-based learning pedagogy). As one first-year student succinctly described, simply *"getting bad grades back and being able to resubmit for more points"* was impactful. For larger projects multiple students reported something akin to the following (also from the senior level capstone course):

"There was a lot of resilience required in continuing the project to completion. We ran into a lot of obstacles where we could have taken a short cut, but we persevered through to turn in the best possible project we could." - 4th Year Student.

Tables 6: Top 2-3 course experiences related to each intellectual virtue growth

Intellectual Virtue	Course Experiences Students Associated with Intellectual Virtue Growth
Critical Thinking	1. Challenging ***open-ended*** homework and test exercises 2. Hands-on projects that require ***troubleshooting***
Creativity	1. ***Projects*** (open-ended, design) 2. Problem-solving needed during ***labs***
Curiosity	1. Engaging lecturers 2. Connecting learning to real-world applications and current events, case studies 3. Exposure to unexpected information
Intellectual Humility	1. ***Mastery learning*** approach to teaching – students supported to try, fail, get feedback, and resubmit assignments 2. Reaching own limitations in academic performance 3. ***Receiving feedback*** from instructor, external experts, and peers

Critical thinking was most attributed to open-ended problems, be they homework exercises or hands-on labs and projects that require troubleshooting was captured by the following student quote from a student in a controls and instrumentation course:

"When issues arose with our circuits labs we had to think methodically to determine what was the issue and address that we were taught how to examine our circuit to find out what was wrong." – 3rd Year Student

Creativity was similar to critical thinking in that students reported it was needed when facing open-ended challenges and problem-solving. Additionally, creativity is fostered when working on flexible or innovative design projects.

Curiosity was attributed to exposure to salient current real-world engineering applications and new information more broadly as exemplified in the quote below by a capstone design student.

"*This course exposed me to many things I had never seen before and sparked curiosity in learning more about those things, as well as just generally being more aware/curious about the world around me." – 4th Year Student*

C*uriosity* can also be facilitated by faculty who promote it in class via diverse examples and encouraging students to explore new topics encouraged. as evidenced by a student comment in the transport phenomena course.

> *"[The professor] did a great job of facilitating my curiosity through mindful comments and examples in class." - 2nd Year Student*

For *intellectual humility*, students again reported that as for resilience, the opportunity to try and fail and resubmit assignments (mastery-based learning) was a leading explanation for cultivating *humility*. Similarly, *humility* grew when classwork was challenging enough that students were forced to face their limits and seek help and receive feedback, as evidenced by the following quotes:

> *"There were a lot of new topics that I had not seen before so I needed to recognize when I was confused so I could seek help." – 3rd Year Student*

> *"Design reviews in showcasing what was done, challenges, and risks and/or roadblocks to receive feedback on. Additionally, capstone meetings with technical coaches." – 4th Year Student*

Tables 7: Top 2-3 course experiences related to each civic virtue growth

Civic Virtue	Course Experiences Students Associated with Civic Virtue Growth
Purpose	1. Connecting learning to ***real-world applications*** and ***current events*** 2. Reflecting on the connection between course content to own ***personal and professional goals***
Service	1. Projects with direct ***connection to the real-world*** and ***real-world stakeholders*** 2. ***Service to peers*** during ***group work*** or exam preparation
Justice	1. ***Self-advocacy*** in the context of group work 2. ***Projects*** with direct connection to the ***real-world and stakeholders*** 3. Exposure to and ***reflecting*** upon real-world engineering applications, ***case studies that involve injustices***

Students felt *purpos**e*** was mostly supported whenever course content was either explicitly connected to current and future oriented real-world engineering applications or their own personal and professional goals. When prompted about the cause of their growth in purpose, this first-year student reported that "*Both [class] projects helped me see what kind of engineering I want to do and how I can use my skills,"* and a second-year student explained, *"After this course, I feel confident in a lot of different topics in engineering…used in the real world to advance society."*

Service was among the least reported areas of growth, but when students perceived growth, they attributed it to when they were able to see the connection between their course projects and how they could benefit communities. For *example, a first-year student said, "The Water Project showed me how I could use engineering to help the environment and improve water quality for communities."* Interestingly, service growth was also reported within the classroom when choosing to support peers in need.

Justice growth was reported rarely but when reported was linked to connecting engineering coursework to real-world applications and stakeholder needs, and also as with service, to intra-classroom dynamics. Students experienced practicing seeking justice for themselves and their peers:

> "*I used justice when completing the right amount of work in the labs and standing up for myself if my classmates were not doing enough of the work." - 2nd Year Student*

Tables 8: Top 2-3 course experiences related to each moral virtue growth

Moral Virtue	Course Experiences Students Associated with Moral Virtue Growth
Honesty	1. ***Mastery learning approach*** to teaching enabled students to ***self-reflect and self-assess*** their limitations 2. Opportunities to ***give/receive honest feedback to/from peers*** 3. Learning about the role of ***honesty in ethics case studies***
Courage	1. ***Communication*** – speaking with stakeholders, giving presentations, speaking in front of a group 2. Facing large challenging assignments
Empathy	1. Projects with direct connection to the ***real-world and stakeholders*** 2. ***Group work*** with peers 3. ***Professor modeling empathy*** in lectures or interactions with students

Course experiences that promote *honesty* overlap with pedagogical approaches that foster *resilience* and *intellectual humility* as well. This includes being supported to reach limits and fail and try again (mastery-based learning) and receiving feedback from professors or peers. Additionally, students report becoming more honest when working on a team as noted by a capstone design student:

> "*Having to work with three other people forced me to be honest with them in order to establish a relationship built on trust. Honesty also helped to move the project forward and to respectfully/critically evaluate each other's ideas." – 4th Year Student*

Lastly, explicitly learning about the role of honesty in real-world engineering ethics case studies was helpful as well.

> "*The ethics discussion allows me to have a deeper understanding of what honesty means to an engineer." – 2nd Year Student*

Courage was primarily needed in the context of communication, be it speaking with stakeholders, giving presentations, or speaking in front of a group. One relevant quote below comes from the transport phenomenon course where students were required to present experimental findings to peers and instructors and solicit feedback.

> "*My courage was facilitated through presenting in the class, where we would solve something and then explain to the class what we did to come to our conclusion." – 2nd Year Student*

Additionally, *courage*, as with critical thinking and creativity, was required when facing large or open-ended challenging assignments. According to this third-year student in the computational modeling course, **"***The problem- solving labs took courage to begin them - especially because you might begin with the wrong solution or answer."*

Empathy growth was attributed to connecting to others, such as external stakeholders or internal teammates in a design project, or professors showing empathy to students. These themes are illustrated well by the following student quotes:

> "*...empathizing with those who are affected by our problem. Understanding their situation helped us better design our prototype with specific attention to the shortcomings of current failing solutions." – 4th Year Student*

> *"Working on a team, being there for my teammates, and communicating…about strengths and weaknesses." - 2nd Year Student, Transport Phenomenon Course*

> "*My professors and TA's were super understanding throughout the semester." - 3rd Year Student*

Tables 9: Course experiences related to integrated virtue growth

Integrated Virtue	Course Experiences Students Associated with Growth
Practical Wisdom	1. Reflections on and making decisions about their own performance as a student and teammate. 2. Being in a decision-making position in the context of design projects. 3. Exposure to and reflecting upon real-world engineering applications, case studies.

Practical wisdom, as the integrated virtue, is indirectly cultivated through growth in all of the other virtues, but students reported direct growth in practical wisdom when prompted to reflect and practice making decisions, as the quotes below illustrate:

> *"There was practical wisdom in managing all of the different deliverables. Some assignments and things were more important to our project than others, so having the practical wisdom to prioritize and practice good project management was critical." – 4th Year Student, Capstone Design Course*

> *"We were given the choice to pick between certain sensors and other components but we would always think about what would be more beneficial for our client. we also thought about what the best approach to do certain tasks would be, such as who was in charge of coding, writing, and other aspects of the project" – 4th Year Student, Capstone Design Course*

> "*Gaining general knowledge in the engineering world, specifically biomedical and environmental engineering." – 1st Year Student*

VI. Discussion

The aims of this study were to bridge two primary obstacles to character-based engineering ethics education: (1) low student engagement in engineering ethics education and (2) engineering educators' reported lack of confidence, competence, or time to incorporate character education into their classrooms.

This study addresses lack of student engagement by analyzing student perspectives on classroom experiences that do effectively impact their character development. The findings revealed that a range of course experiences, including many that align with traditional engineering classroom pedagogies and require little change for engineering educators can result in student character growth, thus addressing the second obstacle of faculty confidence, competence, and time.

Based on the findings, Table 10 below provides suggestions to engineering instructors on how to foster specific character virtue growth with small modifications to traditional engineering

pedagogies that include: lecture, problem-solving exercises (i.e., homework and exams), lab experiments or other hands-on experiences, projects, and review of case studies. The right-hand column provides suggestions for how to best leverage these traditional pedagogies to enhance character development. For example, labs or hands-on experiences are most likely to result in growth in critical thinking and creativity if the lab requires students to troubleshoot obstacles, as opposed to a lab that simply requires following instructions. Lectures can support curiosity and empathy growth if the lecturer models these virtues. These are a few examples from the content featured in Table 10, but this is not an exhaustive list.

For engineering educators who are open to incorporating less traditional pedagogies, student findings also showed that structuring the course to include (1) a mastery-based learning approach, (2) giving students more opportunities to determine their own project topics, and (3) dedicated time for students to reflect (written or discussion) on real-world engineering scenarios and their own personal and professional goals all will further enhance student character development.

Though student reporting only provides one perspective, the findings from this study are consistent with emerging research on evidence-based pedagogical strategies to cultivate character virtues in undergraduate students according to character experts. Such strategies include engagement with virtuous exemplars (e.g., professors modeling virtues), friendships of mutual support and accountability (e.g., student reported peer encouragement and support), habituation through practice (e.g., student reported experience being on a team, repeated practice troubleshooting in labs, working on open-ended projects, having decision-making opportunities), and personal reflection (e.g., student reported reflection) [28].

Table 10: Character growth supported by traditional engineering pedagogies with intentionality

Traditional Engineering Pedagogy	Virtue Growth Supported	As long as...
Lecture	Curiosity	The lecturer is enthusiastic about the topic and/or models curiosity The content is new and unexpected for students
	Empathy	The lecturer models empathy
Problem-solving exercises	Critical Thinking	Problems are challenging, complex, and open-ended
	Resilience	
	Intellectual Humility	
	Courage	
Labs, Hands-on Experiences	Critical Thinking	Troubleshooting is needed
	Creativity	
Projects	Teamwork	Projects are completed in groups Students are in the same group for semester/year
	Resilience	Troubleshooting is needed Obstacles are present
	Critical Thinking	Problems are complex and open-ended Troubleshooting is needed
	Creativity	
	Courage	There is a direct communication with external stakeholders
	Empathy	There is a direct connection to the real-world and stakeholders There is opportunity to connect with peers when working in groups
	Service	There is a component of direct service of others (teammates or external stakeholders)
	Justice	There is direct connection to real-world injustices
Case Study Review	Curiosity	Scenarios are current and presented in the larger societal/global context
	Honesty	There is explicit discussion of the role of honesty in the case study reviewed
	Purpose	Scenarios are current and presented in the larger societal/global context
	Justice	
	Practical Wisdom	Scenarios do not have clear right or wrong answers

Limitations of the Study

The primary limitations of this study lie in the methodology. The data source was limited to student self-reporting, and all self-reporting is subject to bias [41], [42]. Qualitative methods were not as rigorous as would be needed for a more conclusive study given that a single researcher conducted analysis of the terse and at times unclear student open responses. In some cases, student responses indicated that their interpretation of the virtues, particularly justice and practical wisdom, were varied despite being provided with a shared definition. Additionally, there was no control study and since all faculty had been implementing deliberate character education in some form, it is unclear how that background influenced the unintentional character growth in the classroom. Follow-up quasi-experimental studies or more targeted survey questions and in-depth focus group interviews that include instructor perspectives to triangulate student self-reporting are needed. Lastly, given that performance, intellectual, and civic virtues do not have an inherent moral dimension which is critical to ethical decision-making, it is insufficient to study growth in individual virtues for the purposes of ethical decision-making development. Further study of the interconnection of moral and other virtues as well as cultivation of practical wisdom is warranted for this reason.

VII. Conclusion and Future Directions

The purpose of this study was to explore student perspectives on character development within the undergraduate engineering experience. Findings provide insight not only into what course experiences were impactful to students, but also that these experiences were oftentimes unintentional and implicit in common classroom pedagogies. The fact that students reported growth in character strengths even in the absence of intentionally designed character-based coursework is a preliminary indication that undergraduate engineering education may already have numerous opportunities for character education embedded in the curriculum. Performance and intellectual virtues, such as *teamwork*, *resilience*, *critical thinking*, and *curiosity* fit most naturally to traditional approaches to engineering education and can serve as a starting point before focusing on the more elusive moral or civic virtues. For engineering faculty who do not feel equipped to incorporate character education into their courses, rather than designing separate lessons or modalities, they may be able to have significant impact simply by making small shifts in their classroom and by making explicit the connections between existing course content and character development when such opportunities arise.

Given that this is an exploratory study, more rigorous research studies are warranted. Studies designed to determine whether there is a causal relationship between certain course pedagogies and character growth, and longitudinal studies testing the hypothesized relationship between students' practical wisdom growth and their ethical decision-making abilities in their professional engineering practice after graduation are potential next steps.

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