Cultivating Character Through Student-Centered and Mastery-Based Learning: A Case Study in a Thermal Fluids Engineering Course

Olga Pierrakos, Ph.D.
Professor
Wake Forest Engineering
Winston Salem, NC, USA
pierrao@wfu.edu

Saami K. Yazdani, Ph.D.
Professor
Wake Forest Engineering
Winston Salem, NC, USA
yazdanis@wfu.edu

Jessica Koehler, Ph.D.
Senior Research Scholar, Program for Leadership and Character
Winston Salem, NC, USA
koehlerj@wfu.edu

Abstract — **This research-to-practice full paper describes an investigation connecting a student-centered learning environment, grounded on mastery-based learning, to the cultivation of character (e.g. resilience, humility, courage, honesty, etc.). The evidence in support of student-centered pedagogies in the engineering classroom is overwhelming and many engineering programs have been promoting such pedagogies to not only improve learning but also to create more welcoming and inclusive classroom cultures. When combining student-centered pedagogies with motivation theories - like achievement goal orientation - the outcomes are even greater. In fact, engineering education research has demonstrated how student-centered pedagogies combined with motivational theories support not only learning and competencies, but also student engagement, motivation, identity development, belonging, and retention. Mastery-based learning is one student-centered pedagogical approach grounded on achievement goal theory and that supports many of these positive student aspects. In this paper, we will discuss not only the unique mastery-based learning model applied in a flipped classroom collaborative learning format used in a sophomore-level thermal-fluids engineering course, but also present evidence on how this pedagogical approach supports the cultivation of character. Virtue ethics lays the foundation for cultivating character. We discovered that promoting mastery approaches to learning empowered the learners to take ownership of their learning and to also cultivate character strengths like resilience, humility, courage and other virtues. Asking students about their learning gains within a mastery-based learning classroom environment, we have gained new perspective around the additional benefits of student-centered pedagogies grounded on motivation and cultivation of character. In this paper, we discuss classroom structures, learning structures, reward structures, etc. Assessment results showcase student responses to the learning environment and character cultivation. The implications for engineering and STEM educators are many. To the best of our knowledge, this is the first publication to show links between student centered learning environments, such as mastery-based learning, and character cultivation.**

Keywords—Mastery based learning, character, engineering education, thermal fluids.

I. INTRODUCTION

Despite research and national reports urging for more active learning pedagogies, student-centered instructional approaches, and engaging classroom structures and practices (Hadgraft and Kolmos, 2020; Borrego et al., 2010; Smith et al., 2005), engineering education continues to see a predominance of lecture-based classroom environments. Over the years, engineering educators have embraced pedagogies like problem-based learning, project-based learning, flipped classrooms, cooperative learning, mastery-based learning, inquiry based learning, and other inductive learning pedagogies. ***The benefits of such student-centered pedagogies, especially when grounded on psychological and educational learning theories, are immense and continue to be revealed.*** The benefits include learning effectiveness, professional preparation, inclusive and engaged classrooms, retention, degree completion, community building, belonging, personal growth and development, etc. At a time when higher education is under attack for many inadequacies – cost, learning gains, value, accessibility, outdated curricula, outdated pedagogies, etc. – it could not be more imperative to showcase even more advantages to student-centered and theoretically-grounded pedagogies in higher education.

In the same way that higher education has a responsibility to educate citizens for the common good and for meeting societal needs towards human flourishing, ***it is also imperative for the next generation of engineers to be educated with not only technical competencies but also leader character*** [Crossan et al., 2022]. This is backed up by literature over the past decades that points to ***the need for engineering education to rethink classroom learning towards whole engineer education as essential*** and encompassing topics like ethics, professional responsibility towards public and societal welfare, social conscious engineering, empathy, etc. [Hitt et al., 2023; Cech 2014; Pierrakos et al., 2019].

Given the above claims, what role do effective pedagogies play in the development of a whole engineer and the development of character as a core competency for engineers? This paper thus represents an exploratory study to gauge the impacts of a student-centered, mastery-based learning pedagogical classroom model on the cultivation of character development.

The guiding **research questions** in this investigation are:

(1) To what extent can character be cultivated in a student-centered mastery-based learning classroom environment?
(2) What are students' perceptions of classroom experiences that lead to the cultivation of character and virtues?

To the best of our knowledge, this publication is the first within the engineering education literature to build connections between effective student-centered learning environments and character cultivation.

II. Theoretical Grounding of Mastery-based Learning: Achievement Goal Theory

Considerable research has focused on how classroom learning environments impacts student learning. A large focus of such research has been on how the classroom environments influence students' views and attitudes towards learning, but also important is research on students' own motivations and how they think of themselves in the context of a learning environment and the process of learning. Certainly, specific goals, structures, and learning activities in a classroom can influence students' orientation and attitude towards learning.

There are many motivation theories in educational settings focus on the structures and processes that impact and explain goal-directed activity for students. Motivation theories in education research have been used to explain students' decision making and activity selection, engagement, help seeking attitudes and behaviors, persistence, performance, learning attitudes, etc. ***Achievement goal theory*** is one prominent motivational theory guiding us in understanding students' achievement motivation, including attitudes and behaviors in educational settings (Meece et al, 2006; Anderman & Wolters, 2005; Pintrich, 2000; Ames, 1992). In a learning environment, achievement goal theory suggests that students with a ***mastery goals orientation*** (i.e. a focus on mastering new knowledge and skills as a means to increase understanding and competence) in contrast to those with a ***performance goals orientation*** (i.e. a focus on achievement through external recognition comparing with others) reveal a more positive achievement pattern and persist at difficult tasks (Stipek & Kowalski, 1989; Elliot & Dweck, 1988), put more effort on tasks (Wolters, 2004; Grant & Dweck, 2003); show strong engagement with a task (Harackiewicz et al., 2000), positive perceptions of self-efficacy (Wolters, 2004; Midgley et al., 1998; Meece et al., 1988), and a stronger sense of belonging (Anderman & Anderman, 1999). Situational factors can alter the salience of students' goal orientation preferences (Pintrich, 2000).

Achievement goal theory points to the importance of goal structure of the classroom learning environment and how this environment might affect students' motivation, cognitive engagement, and achievement (Wolters, 2004; Ames & Archer, 1988). Goal structure describes the type of achievement goal that is inherent by the prevalent instructional structures, practices, and policies within a classroom learning environment (Wolters, 2004). Factors such as type of tasks assigned, degree of student autonomy, the way student groups were formed, grading practices, types of incentives and rewards, etc. impact goal structure and ultimately students' achievement goals and orientations. In an academic setting, a mastery goal structure is an environment that through its instructional structures and practices convey to students the importance of learning, the importance of inclusion of all students, the importance of effort, and that all students can be successful if she/he work hard to learn (Wolters, 2004; Mindgley et al., 1998). In contrast, a performance goal structure is an environment that conveys to students focused competition for grades and social comparisons of ability. Several studies speak to the significance of classroom goal structures influencing both student learning, behaviors, and shaping students' personal goals, which correspond to their perceptions of the classroom goal structure (Urban 2004; Roeser et al., 1996; Anderman & Midgley, 1997). Educators have the capacity to influence the adoption of mastery goals, through autonomy-supportive practices in classrooms (Benita, 2021).

Resilience or grit, which includes consistency of interest and perseverance of effort, has been associated with academic achievement (Duckworth, Peterson, Matthews, & Kelly, 2007; though see Sheridan & Carr, 2018), goal commitment (Tang, Wang, Guo, & Salmela-Aro, 2019), self-efficacy (Usher, Li, Butz, & Rojas, 2018) and physical and mental health (Forbes & Fikretoglu, 2018; Liu, Fairweather-Schmidt, Burns, & Roberts, 2015).

III. Theoretical Grounding of Character Cultivation

Engineers have an incredible responsibility to society towards not just public welfare but human flourishing. This responsibility is built on professional ethics for the betterment of humanity. Our prior work has pointed to the opportunity to rethink engineering ethics in the engineering classroom. Virtue ethics is a missing link to the more traditional ethical frameworks – deontology and consequentialism - covered in engineering classrooms (Pierrakos et al., 2019). Virtue ethics helps us lay the underpinnings of cultivating character. Virtues are a set of aspirations and "core characteristics as defined by moral philosophers and religious thinkers" (Peterson and Seligman, 2004) that guide our thoughts, feelings, and behaviors towards morally good ends. There are many classifications and frameworks of virtues and example virtues include honesty, courage, humility, curiosity, resilience, justice, etc. Character is a collective set of virtues that define one's disposition guiding thoughts, feelings, and behaviors. Our previous work has pointed to virtues that are prominent in engineering education (Koehler et al., 2020) and prominent in engineering professional codes of ethics (Boatman et al., 2024). Virtues help us understand character and we have explored students' perceptions of character cultivation in the engineering classroom (Koehler et al., 2023). Based on our prior work, some virtues relevant to engineering education and engineering practice are shown in Figure 1. This is not an all-inclusive list. The color

reflects the categorization of virtues offered by the Jubilee Centre Framework which divides virtues into four categories: performance, intellectual, moral, and civic (Jubilee, 2022). All of these virtues culminate into one integrated virtue - practical wisdom.

Cultivation of character has recently been guided by seven strategies (Lamb et al., 2021):

(1) habituation through practice
(2) reflection on personal experience
(3) engagement with virtuous exemplars
(4) dialogue that increases virtue literacy
(5) awareness of situational variables
(6) moral reminders, and
(7) friendships of mutual accountability.

Although these strategies are not a pedagogical model, leveraging these strategies in the context of achievement goal theory (motivational theory) towards a mastery-based and student-centered pedagogical approach is part of this exploratory study.

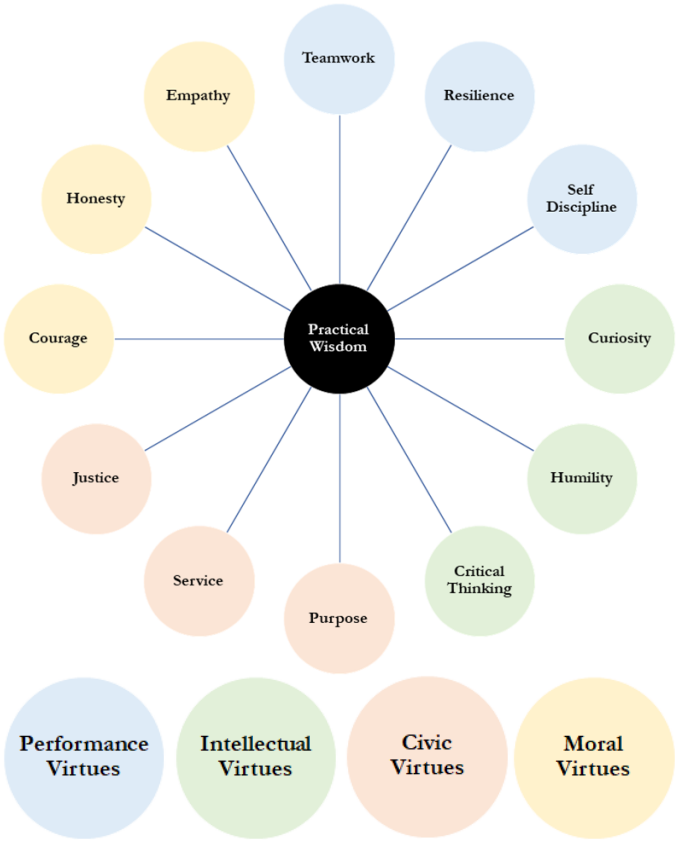


Figure 1: Virtues relevant to engineering education and engineering practice informed by our prior research and the Jubilee Centre Framework.

IV. Course Details

The course that is the context for this investigation is a sophomore engineering course at Wake Forest Engineering (WFU). This course supports students' development to understand thermal-fluid engineering systems from the lens of conservation principles (e.g. mass, energy, momentum) and also begin to understand the decisions that engineers make in the design and improvement of such systems. The class offers an integrated approach to learning fundamentals of thermodynamics, fluid mechanics, and heat transfer. Frequently identified by students as one of the more difficult subject matters in most engineering programs, the complexity of engineering fundamentals (i.e. conceptual thinking, engineering principles, engineering problem solving, and connections of topics) within this course have also been found to challenge our students at WFU. The specific learning outcomes for this course are:

1. Characterize and analyze a diverse sample of thermal fluid systems using conservation principles of mass, momentum, and energy.
2. Conduct experiments on basic thermal-fluid systems to understand fundamental concepts and apply conservation principles with a keen focus on describing sources of error and uncertainty analysis.
3. Reverse engineer and model a real-world engineering thermal-fluid system to understand its performance across technical and human domains.
4. Demonstrate literacy of course content using written and oral forms of communication.
5. Develop strategies to support one's mastery learning and a resilient mindset.

The course was pedagogically designed to be a **flipped classroom experience** where students spend a good amount of class time working out engineering problems and conducting labs, plus receiving feedback on their semester-long course project in the presence of faculty instructors. A flipped classroom pedagogical model enables instructors to reduce lecture time during class and increase activities like working out problems collaboratively, making lab presentations, sharing knowledge on data analysis best practices, and conducting frequent peer reviews on an independent course-project. This allowed reading, completion of a prep guide, and assignment completion outside of class. The flipped classroom nature in this course enabled students to work in small groups during every class period. This provided an informal means of peer support and peer accountability to complete the course activities and aim for a higher performance. To put things into perspective, in a flipped classroom environment, we worked out over 100 problems together in class. It also became common practice for students to make their work visible to each other, and this enabled a form of peer accountability. With a flipped classroom approach, students work in pairs or small groups (3-4) in class to solve problems, to complete labs, and to provide each other feedback on project checkpoints. The pairs or lab groups were frequently changed to allow all students in the class to change partners and build a strong working relationship with all peers in the class. This collaborative structure helps build very strong bonds and evident friendships. This was very evident in our labs, as students could work together to set-up,

record and analyze data together in groups. Each group of students would then share their data and calculations to the entire class, increasing the collaborative nature of the course. This strategy was immensely successful towards students' learning performance, resilience, collaborative work, and building community within the class.

The course was also designed to support **mastery based learning** by allowing students to take ownership of their learning by enabling students to perform additional assignments and re-submit assignments which reflect low performance (upon a minimum initial performance being met). In class, we implemented the use of Mastery Points as a mechanism to reward perseverance of effort, quality of effort, active engagement in class, supporting peers with mastery, and submitting quality work above a certain threshold. Mastery points was available in all aspects of the classroom including homework, in class assignments and labs. A small percentage of the Mastery Points get added to the students' final grade. All students took part in earning Mastery Points and the instructions provided to students as shown in ***Figure 2***. We also enabled students to resubmit graded work (upon a minimum initial performance being achieved) as an optional means for the students to show deeper mastery to earn back some points on their graded assignments. The striving goal was putting in extra effort to lead to mastery and stronger engineering practice. We also implemented no deadlines on the mastery based learning, allowing the students to turn in any mastery assignment by the last class of the semester.

In addition to Mastery points, we embedded several discussions, preceded by videos, guest lectures, and readings, to both directly and indirectly connect to the virtues of grit and resilience within the entire semester. The following activities reflect these activities.

Week 1 – Show Angela Duckworth's "Grit" Ted Talk and discuss perseverance of effort as a means to mastery as a class goal.

Week 3 – Discussion on "What does it mean to be an expert?" followed by calculation of how many hours one spends on engineering practice during college years.

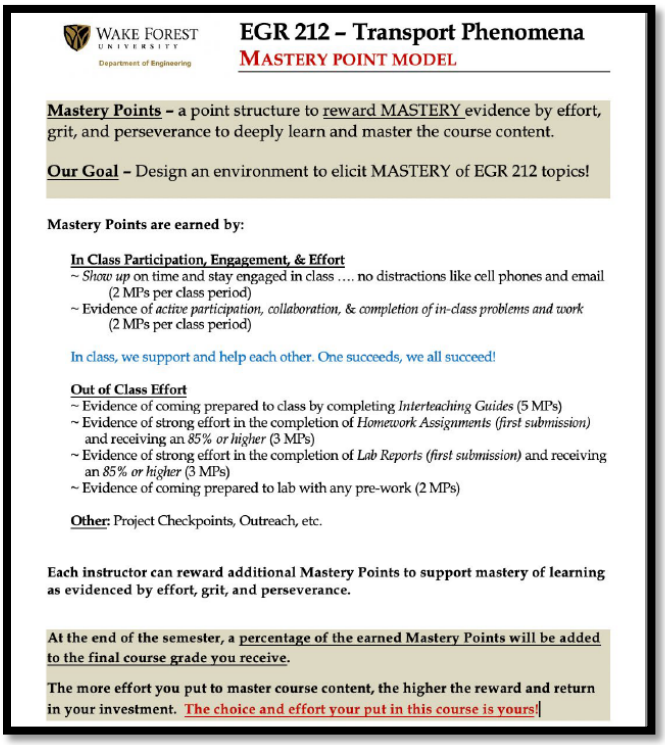
Week 6 – Discussion on deliberate practice referencing psychology research and providing examples beyond engineering, including sports and music examples [Ericsson, 2008; Krampe and Ericsson, 1995; Ericsson et al., 1993].

Week 7 – Midpoint reflection on self-performance and development of an action plan to meet self-derived performance goals.

Week 15 – Discussion about "achievement of mastery" as an end-of-class reflection topic.

Two formal points of reflection enabled students to reflect on their performance in the class and identify actionable strategies to improve one's academic performance towards meeting personal and professional goals. The mid-semester reflection is an assignment to enable students to reflect on their performance in the class across the various areas of performance (e.g. homework, quizzes, exams, labs, and course project, earned mastery points). Upon reflecting on their performance to date, they are asked to set a target goal of performance for each category and develop a specific action plan with specific strategies to reach the target goal.

The end of semester reflection enables students to look back at their performance during the semester and reflect on the goals set, strategies to meet the performance goals, and a reflection of whether or not the target goal was attained. Our goal of these activities and discussions were for students to (1) better understand and describe the virtues of grit and resilience as applied to evaluating one's performance towards meeting personal and professional goals; (2) reflect on one's academic performance in the context of this course and identify actionable strategies to improve one's academic performance towards meeting personal and professional goals; and (3) reflect and apply resilience and grit as virtues towards personal growth and professional practice. ***Figure 3*** shows the reflection prompt.



WAKE FOREST UNIVERSITY
Department of Engineering

EGR 212 – Transport Phenomena
MASTERY POINT MODEL

Mastery Points – a point structure to reward MASTERY evidence by effort, grit, and perseverance to deeply learn and master the course content.

Our Goal – Design an environment to elicit MASTERY of EGR 212 topics!

Mastery Points are earned by:

In Class Participation, Engagement, & Effort
~ *Show up* on time and stay engaged in class …. no distractions like cell phones and email (2 MPs per class period)
~ Evidence of *active participation, collaboration, & completion of in-class problems and work* (2 MPs per class period)

In class, we support and help each other. One succeeds, we all succeed!

Out of Class Effort
~ Evidence of coming prepared to class by completing *Interteaching Guides* (5 MPs)
~ Evidence of strong effort in the completion of *Homework Assignments (first submission)* and receiving an *85% or higher* (3 MPs)
~ Evidence of strong effort in the completion of *Lab Reports (first submission)* and receiving an *85% or higher* (3 MPs)
~ Evidence of coming prepared to lab with any pre-work (2 MPs)

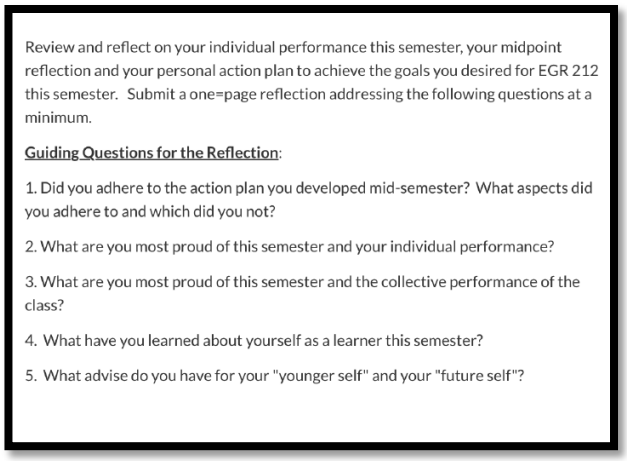
Other: Project Checkpoints, Outreach, etc.

Each instructor can reward additional Mastery Points to support mastery of learning as evidenced by effort, grit, and perseverance.

At the end of the semester, a percentage of the earned Mastery Points will be added to the final course grade you receive.

The more effort you put to master course content, the higher the reward and return in your investment. The choice and effort your put in this course is yours!

Figure 2: Mastery Points Model implemented in the Wake Forest Engineering Transport Phenomena course as part of the mastery-based learning model.



Review and reflect on your individual performance this semester, your midpoint reflection and your personal action plan to achieve the goals you desired for EGR 212 this semester. Submit a one=page reflection addressing the following questions at a minimum.

Guiding Questions for the Reflection:

1. Did you adhere to the action plan you developed mid-semester? What aspects did you adhere to and which did you not?
2. What are you most proud of this semester and your individual performance?
3. What are you most proud of this semester and the collective performance of the class?
4. What have you learned about yourself as a learner this semester?
5. What advise do you have for your "younger self" and your "future self"?

Figure 3: End-of-semester reflection prompt.

V. METHODS

We collected responses from students during end-of-course evaluations over the course of two semesters. Although there were some differences across the course being offered across two semesters, the overall pedagogical approach, learning structures, learning activities, and character cultivation activities remained the same. Open ended questions and Likert scale questions were part of the end-of-course reflection survey. Open ended questions offered us insights about specific aspects of the course and Likert scale questions offered quantitative insights that allowed comparative insights to be gained. The participation of survey completion was high for both courses – 100% for fall 2019 and 85% for spring 2020.

In regard to gaining insights into student perceptions of character strength development, one survey question asked students to select character strengths from a predetermined list (creativity, curiosity, critical thinking, service, empathy, courage, resilience, honesty, justice, purpose, teamwork, intellectual humility, and practical wisdom). First, students were asked to select the virtues that they perceived development during the course and then they were asked to respond to an optional open-response prompt asking about aspects of the course that facilitated their growth in that character strength. A previous publication (Koehler et al., 2023) includes more details about the item development process.

VI. RESULTS AND DISCUSSION

The following quotes are representative of student feedback about the course. The guiding prompt was ***"What helped your learning in this course?"*** There are several themes that emerged from these student responses. One theme was the value of collaborative learning and how instructors and peers played a critical role to support the learning. Students spoke about the role of peers and instructors supporting their learning achievements and the class structures that supported that learning. The continuous reminders of mastery from week one of the class to the last week served to motivate students. The mastery points model served as a reminder too and a continuous reward structure promoting competency through effort. Other emergent themes involved feedback about particular aspects of the course and included considerable mentions of the mastery-based learning model and the flipped classroom model (e.g. interteaching guides). Students were incentivized in many ways to take ownership of their learning during this course. This empowerment had impacts in cultivating character and this will be discussed next.

> *"Utilizing my **peers** was the biggest takeaway from this course. We had a very small class, so we made a constant effort to **work together through challenging topics**. Everyone has valuable ideas and inputs and it took a lot of my stress away to work together. I also think the **concept of mastery work helped motivate me** a lot. I would rather be focused on what I can learn and how I can do that best, than stressing about grades only. I think the fact that we can **resubmit**, do **take home exams**, and **work together on homework** made me more motivated to figure things out instead of worrying about the score."*

> *"My **persistence and willingness to never give up** until I understood the material. I usually would not understand the material completely after we covered it in class. Also, I am lucky that **my classmates** are very helpful and nice enough to help me with the topics that I do not understand."*

> *"The **various different approaches** to the same subject was very beneficial in my understanding. For example, learning about closed systems through discussion in class, an interteaching guide, and a workout problem assignment allowed me to understand the material a lot better."*

> *"The **collaborative learning** style in class!"*

> *"During the class lectures I found having more than one professor to be helpful in my learning. One instructor could be talking to the class while the other could be individually helping one student. I found this made asking questions and getting answers easy. The textbook as a resource really helped me teach myself on my own and helped me get better doing workout problems. Lastly, the **mastery model helped me understand where I went wrong and encourage me to revisit my mistakes which helped me absorb the material**."*

> *"The **Interteaching guides** helped introduce me to the material before it was presented in class so even though I often did not understand some concepts, I knew the general ideas when we had lecture."*

In regard to character strength cultivation, Tables 1 and 2 offer us insights stemming from the students. ***Table 1*** shows the quantitative results of asking students "what character strengths

did this course help you develop?" and ***Table 2*** shows themes emerging from open-ended questions about "what aspects of the course facilitated your growth in ___?" With 100% agreement from students, resilience, courage, and humility were developed as part of the course. Column 2 of Table 1 shows the category of virtue in alignment with what was described in Figure 1. Resilience is a performance virtue, courage a moral virtue and humility an intellectual virtue. We mention this because it is nice to see that a diversity of virtue categories was identified by students as being cultivated. In alignment with what we have observed in prior investigations, performance and intellectual virtues tend to drive character cultivation in engineering classrooms and intentionality is needed to cultivate moral and civic virtues (Koehler et al., 2023).

Starting with the virtue of ***resilience***, students identified the extreme workload (many students noting 15+ hours of work outside of class) and difficulty of the course as the thing that cultivated resilience. Associated quotes from students are below and these responses point to the mastery-based learning model of the course incentivizing learning through failure and working towards mastery through effort and perseverance. Two distinct students noted the following regarding cultivating resilience in the course.

> *"Failing and trying really hard not to fail again, then failing again."* – Student Response to Cultivating Resilience

> *"The course gave a lot of work to do, but I was able to keep moving forward and complete most of the work."* – Student Response to Cultivating Resilience

Courage was cultivated through failure also and we observe links in students' responses between the cultivation of resilience and courage through failure. Students spoke to not having the right answer and having to figure out why. This cultivated resilience and courage. Making failures (or a lack of mastery) visible to the class during presentations of lab results or working out problems in class demonstrated courage and resilience. One student noted the following quote below and we believe this is a reflection of the mastery-based learning model of the course. Getting a problem wrong and attempting it again was seen as courageous. Similarly, presenting lab results that students knew were wrong to welcome feedback from instructors and peers in class was courageous to them.

> *"Attempting problems after failing."* – Student Response to Cultivating Courage

Through teamwork and reflection, students developed their ***humility***. As noted in the quotes below, students recognized their weaknesses and worked to improve them and/or seek guidance. This self-awareness was crucial to fully mastering the learning in the course and humility played a critical role.

> *"I recognized my weakness and I tried to improved them or seek assistance."* – Student Response to Cultivating Humility

> *"Understanding when I need to work harder on something to fully understand it."*– Student Response to Cultivating Humility

Other intellectual virtues cultivated during this mastery-based flipped classroom courses were ***critical thinking*** and ***curiosity***. Working out difficult problems cultivated critical thinking and gaining mastery involved understanding how new concepts and new knowledge learned in the class applied to diverse engineering applications. The course project most certainly played a role in cultivating critical thinking and curiosity because course projects reflected an engineering application that was of interest to each student and also reflected a problem that did not have one correct solution or one correct path to a solution.

> *"I used critical thinking when attempting difficult homework problems."* – Student Response to Cultivating Critical Thinking

> *"Applying what I learned in class to other systems."* – Student Response to Cultivating Critical Thinking

> *"I wanted to learn more about how the concepts in class applied to real world systems."* – Student Response to Cultivating Curiosity

We were happy to see that moral virtues were cultivated in the mastery-based flipped classroom engineering class. We witnessed connections across performance and intellectual virtues towards moral virtues. As an example, relevant to humility (intellectual virtue), we observed that ***honesty*** (moral virtue) was cultivated. Students recognized this important connection in their articulation of honesty – an honest recognition and self-awareness of one's own abilities was linked to mastery and involved openness with peers, teaching assistants, and the instructors. Comfort in disclosing areas of self-growth and areas where self-mastery was still needed was built into the culture of this course and this allowed growth and achievement.

> *"I was honest to myself, when I was wrong about something and admitting that the other person was right."* – Student Response to Cultivating Honesty

> *"I was honest with the TA when I did not understand a certain topic on the homework."* – Student Response to Cultivating Honesty

Along with virtues important to self-reflection and self-awareness towards learning achievement, we also witnessed virtues that were more civic and moral in nature. This includes virtues like ***justice***, ***purpose***, and ***empathy***.

"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." – Student Response to Cultivating Justice

"After this course, I feel confident in a lot of different topics in engineering that can be used in the real world to advance society." – Student Response to Cultivating Purpose

"I used empathy when someone could not figure out a topic in the class and I took time to explain it to them because I knew it would make me frustrated too." – Student Response to Cultivating Empathy

Table 1: Students' perceptions of virtue development. The color coding maps to the virtue types outlined in Figure 1.

Virtue	Virtue Type	Yes	No	Not Sure
Resilience	Performance	100%	-	-
Courage	Moral	100%	-	-
Humility	Intellectual	100%	-	-
Critical Thinking	Intellectual	87.5%	-	12.5%
Curiosity	Intellectual	75%	-	25%
Teamwork	Performance	75%	-	25
Honesty	Moral	75%	-	25
Empathy	Civic	75%	12.5%	12.5%
Practical Wisdom	Integrated	75%	12.5%	12.5%
Purpose	Civic	62.5%	12.5%	25%
Creativity	Intellectual	62.5%	25%	12.5%
Justice	Civic	62.5%	25%	12.5%
Zest	Performance	62.5%	25%	12.5%
Authenticity	Moral	62.5%	25%	12.5%
Service	Civic	37.5%	25%	37.5%

We also witnessed other performance virtue gains – ***Teamwork*** and ***Zest***. Teamwork was built into the flipped classroom model of the course considering that most of class time was spent on working together as small peer teams and interfacing with the instructor(s) and teaching assistants. Team-based work took place with working out problems, conducting lab experiments, providing feedback on course project progress, etc. In these rich social interaction settings, not only was teamwork cultivated but so was an enthusiasm to understand new topics relevant to course learning. Be weaving into the course a semester-long, student-selected project, each student targeted to apply their learning to an engineering system or application of interest to them. This degree of autonomy helped each student demonstrate their motivation for a topic of interest to them and to show zest in diving deep to understand concepts from the course being applied to a new thermal-fluid engineering system.

"The lab write-ups and presentations required me to be a good team member by organizing meetings and staying on top of my work." – Student Response to Cultivating Teamwork

"I was enthusiastic about researching my course project topic and presenting on it." – Student Response to Cultivating Zest

In summary, we witness in Table 2 that students found many features of the course in supporting cultivation of character. Maybe the most prominent features being the mastery-based learning model that was built on a collaborative flipped classroom structure and also the varying learning experiences that enabled and supported mastery. The course promoted mastery as it progressed students from one correct solution problems (e.g. workout problems) to lab experiments (with write-ups and presentations) that had correct solutions but multiple paths to get there to an independent course project showcasing multiple correct paths to modeling a real-world thermal-fluids system. All this points to the success of leveraging student-centered (aka learner-centered) pedagogies grounded in motivation theories like achievement goal. Intentional use of pedagogies can indeed cultivate character and educate the next generation of engineers with competence and character.

Table 2: Students' perceptions of learning activities facilitating virtue development.

Virtue	Supporting Activity or Experience
Resilience	Tough class, high workload
Courage	Failures, public speaking/presentations
Humility	Teamwork and reflection
Critical Thinking	Workout problems & course project
Curiosity	Course project
Teamwork	Lab reports and presentations
Honesty	Recognizing knowledge limits
Empathy	Helping and understanding peers
Practical Wisdom	Course project
Purpose	Course project
Creativity	Course project
Justice	Sharing the workload with teamwork
Zest	Course project
Authenticity	Course project
Service	Helping peers

VII. Conclusion

In this paper, we have made some important connections between student motivation towards learning, achievement goal theory, mastery-based learning grounded in a collaborative flipped classroom environment, and cultivation of character. We believe this is one of the first engineering education publications to connect the importance of learning theory grounded pedagogy to character cultivation. Intentionally designing and recognizing classroom structures as fundamental to character cultivation is significant to the work of engineering educators.

In our investigation of gauging the efficacy of a student-centered mastery-based learning flipped classroom format to cultivate character, we discovered that virtues like resilience, courage, humility, teamwork, curiosity, critical thinking, honesty, empathy, justice, etc. can indeed be cultivated. Although some virtues were explicitly mentioned during class time (e.g. resilience), we discovered that other virtues were perceived by students to be cultivated and these virtues (e.g. courage, humility, honesty) were not mentioned explicitly during class time. Further, although the evidence provided was based on self-report measures and reflections of learning and development, we gained insight into specific aspects of the course that facilitated student development and growth. We learned that cultivation of character through effective and intentional pedagogical design can make an impact. One can only imagine the impacts of such strategies across entire engineering curricula.

The findings herein have implications for engineering educators and can be applied to most engineering and STEM classrooms. Bringing motivational theories with effective student-centered pedagogies can cultivate character and improve technical learning.

While we do not claim our methodology to be perfect, we recognize methodological limitations. Only one coder was used to identify pedagogical threads mapping to each virtue (Table 2). Some students were more articulate in describing the aspects of the learning that cultivated particular virtues and their quotes were more frequently used in the qualitative data represented in this paper. We encourage future work in this research area of character cultivation in general but also in the important role that effective student-centered pedagogical approaches can play in the development of a virtuous engineer.

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