Scoping Review of Character Development Pedagogies in Engineering Education

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Abstract— **When preparing engineering students for professional practice, the importance of their engagement in global, social, and ethical dimensions of engineering cannot be overemphasized. The importance of ethics is well discussed in engineering education literature, but much less is known about how to effectively prepare graduates for the complex global, social, and ethical challenges of engineering practice. Studies have found that common challenges to engineering ethics education include lack of student interest, resistance from faculty, and a lack of consensus regarding topics and pedagogical methods to include in already saturated curricula.**

We believe a character-focused approach to engineering ethics education could address these challenges by providing language and tools that are easily accessible to students and faculty for engaging ethical challenges in engineering and addressing students' development as individuals and future professionals. This paper investigates recent pedagogical efforts to implement character education in undergraduate engineering education through a scoping literature review. The resulting synthesis of 30 publications reveals a variety of pedagogical approaches, the majority of which are student centered and already commonly used by engineering educators. Our findings indicate that character education is indeed a viable and accessible approach to engineering ethics education. Learning assessment was largely limited across observed interventions, so future studies are needed to examine student and faculty engagement as well as impact on students' ethical decision-making processes.

Keywords—character education, ethics, student centered pedagogies, scoping review

I. INTRODUCTION

Discussion of the need for character education in professional schools has gained momentum in recent years, with a growing consensus that "Professional people are expected to do the right thing; and they are expected to do the right thing both for individuals…and for society at large [1, pp. 2]." Though much of this emerging work has been studied in fields such as medicine, teaching, nursing, law enforcement, social work, military and business [2], [3], character in the engineering field is equally as important. Formal engineering codes of ethics addressing societal health, safety, and welfare date back to the 1940's and more specific ethical codes that guide professional practice within engineering disciplines have been developed over time [4], [5]. Compliance based codes of ethics alone fall short, though, because such codes do not facilitate navigating the complexities of engineering practice [6], [7]. This apparent narrow focus is not a surprise because, by definition, ethics focuses on moral principles. However, for these moral principles to be internalized and made tangible, there is a need to go beyond the principles and think more deeply about what they mean to people, how they apply to relationships with others, and the resulting impact of such relationships on society and the environment. A character virtue ethics approach would focus on developing "character, cultivating stable dispositions to act, think, and feel in ways that enable [engineers] to do the right thing, for the right reasons, in the right ways…[using] a more holistic set of considerations including thoughts, emotions, motivations, habits, dispositions, and actions [7, pp. 2]."

While the importance of engineering ethics and the relevance of character virtues in professional ethical decision-making have been established [4], [6], [7] little is known about how to effectively prepare graduates for engagement in the complex global, social, and ethical dimensions of engineering practice. A number of studies have found that common challenges to engineering ethics education include (a) lack of student interest, (b) resistance from faculty, and (c) a lack of consensus regarding topics and pedagogical methods to include in already saturated curricula [7]–[12]. Additionally, (d) a comprehensive review of research in 2020 showed that although there had been fairly widespread implicit incorporation of character in engineering, the emphasis has been on technical skill building without clear acknowledgment of the ethical and moral dimensions of character [13].

As a step towards centering the ethical and moral dimensions of character in engineering, this paper focuses on understanding the pedagogical strengths and gaps that exist in the integration of character education in engineering education. The present study seeks to explore the intersection of current best practices in engineering pedagogies and character education in engineering to gain insight into how to address the challenges identified above and therefore (a) engage students, (b) identify pedagogies that are accessible and/or familiar to engineering faculty, and (c) facilitate low-maintenance integration of

character education within already rigorous engineering education that (d) includes the moral and ethical dimension of character, not just skills. We believe a preliminary step to address these challenges is to first understand the pedagogies applied in existing implementations of character education in the engineering education field. Consequently, we have approached our study by asking the following research question:

What are the pedagogies currently used in character education efforts within engineering undergraduate programs?

II. Methodology

To address our research question, we conducted a scoping literature review. In various fields, including engineering education, scoping reviews help clarify the coverage of the body of literature on a subject. They serve various purposes such as informing the decisions around initiating a systematic literature review [14], [15]. Other reasons include identifying concepts in a targeted domain and assessing knowledge gaps [15]. These latter two applications informed the present effort. Scoping reviews also typically feature a structured predetermined protocol, a comprehensive literature search and transparent, reproducible process [15].

A. Scoping review protocol

Our scoping review is based on the framework developed by Arksey and O'Malley [16] which other researchers have used [17], [18]. The process involves the following five iterative stages that can be tailored to one's context: a) identify the research question, b) identify relevant studies c) select studies d) chart the data and e) collate, summarize and report the results. The steps are depicted in Figure 1 below.

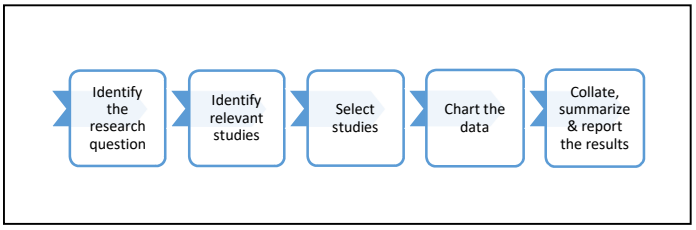

Figure1: Scoping literature review protocol (Adapted from [16])

a) Identifying the Research Question. A previous study has shown that many virtues, especially four prominent ones in the field of engineering education have been implemented in undergraduate engineering, except that they are often taught as skills [13]. However, a character virtue focused approach would emphasize moral growth and development of people, which is beneficial for the flourishing of society. Consequently, the current study focuses on interventions that address virtue or character development. This focus area has guided our overarching research question mentioned above.

b) Identifying Relevant Studies. A focal point of clarification before delving into to the literature – our definition of character education emphasizes character virtues that promote the flourishing of humans and communities and go beyond traditional rule-based approaches to ethics [7], [19]. Consequently, our review of the literature to address the aforementioned research question was guided by the following criteria:

1. Is the effort focused on undergraduate engineering?
2. Does it clearly address either of the three areas below?
    a. Ethics education from a virtue ethics lens
    b. A virtue or character trait (e.g. teamwork or empathy)
    c. A cultivation of character more broadly
3. Does it specify how any of these three areas were addressed pedagogically?
4. Does the reference explain the pedagogical approaches clearly (such that it is evident how the goals/objectives of the intervention connect to the approach used)?

We explored the following three databases: Scopus, IEEE Xplore and ASEE PEER. Scopus provided access to pertinent publications in multiple disciplines including key outlets in engineering education like the Journal of Engineering Education, International Journal of Engineering Education, American Society for Engineering Education conferences and Frontiers in Education conferences. IEEE Xplore provided the advantage of an international platform with publications specifically related to engineering and technology all in one place, bringing our search close to the field of interest. Finally, ASEE PEER was advantageous for showing the landscape in the field of engineering education, which could help uncover resources that other databases may have missed.

It is important to note that in a scoping review, search processes are iterative. Further explanation of this process and the various search terms used in early iterations of the process are described and summarized in Appendix A.

Table 1 below shows the results generated from the final search terms used. These terms encompassed variations of how intentional character education efforts may be labeled.

TABLE 1: SUMMARY OF DATABASE SEARCH AND RESULTS

Search terms/parameters used	Database	Results
"character education" OR "character development" OR "virtue ethics" AND "engineering education"	IEEE	**26**
	Scopus	**40**
	ASEE PEER	**54**

c) Selecting Studies. After completing the searches and identifying relevant references based on our criteria (1, 2a, 2b, 2c and 3) mentioned above, we selected the relevant sources by downloading the search results in spreadsheets and manually sifting through them (a collaborative effort between the first and second author). All the relevant search results from the three databases were consolidated into one spreadsheet and redundant references were eliminated. We then conducted a more granular selection process by reviewing paper titles, abstracts and the bodies of the papers where necessary. We also had iterative discussions among the co-authors to support the reliability of the selection process since there is no vetted definition of what

constitutes character education in the engineering field. Ultimately, our investigation revealed 30 relevant publications.

d) Charting the data. This phase entails a visual aid to help extract key information from the selected studies that are relevant to the research question. These results are reported in the findings that follow.

III. FINDINGS

Across the thirty publications reviewed, character education efforts in engineering demonstrated a range of pedagogical approaches. The most common are case based learning (CBL), project based learning (PBL), service learning, collaborative learning, technology enhanced learning, reflection, discussion and lecture.

Interestingly, single pedagogies were rarely used, and most studies reported various pedagogical combinations. To best present these findings, we grouped the pedagogies into three nested categories (Figure 2): **Global Pedagogy** (Case Based Learning, Project Based, Learning, Service Learning) that provides high level structure and context for learning, **Embedded Pedagogy** (Technology Enhanced Learning, Collaborative Learning) that enriches ongoing learning experiences, and **Discrete Pedagogy** (written reflection, discussion, lecture) that are the more episodic and concrete manifestations of teaching and learning. The global pedagogies tend to be applied in the broader context of a course or course module e.g. *CBL* and *PBL*. The embedded pedagogies are used within the global pedagogical approach to enrich the student experience e.g. working collaboratively (*collaborative learning)* to analyze cases. Discrete pedagogies are sometimes used by the instructor to provide foundational knowledge, such as *lecture* on ethical frameworks. They could also support students' demonstration of learning outcomes such that they could potentially be assessed e.g. engagement in *discussion* or written *reflection* to demonstrate ethical reasoning.

In Figure 2 below, the straight arrow indicates that a global pedagogy can directly involve student demonstration of learning outcomes through a discrete pedagogical approach. For instance, in a CBL environment, written reflection and discussion can be used to directly engage students with ethical cases. An example of this format is the Anti-corruption Training and Globalization module described by [20, pp. 8]. Alternatively, the two curved arrows indicate that a global pedagogy could connect to a discrete pedagogy through an embedded pedagogy. For example, in a PBL environment, students can engage in collaborative projects and within those projects do some team based activities e.g. group discussions. An example of this approach is the description of the fourth ethics module by Frigo and colleagues [6, pp. 23].

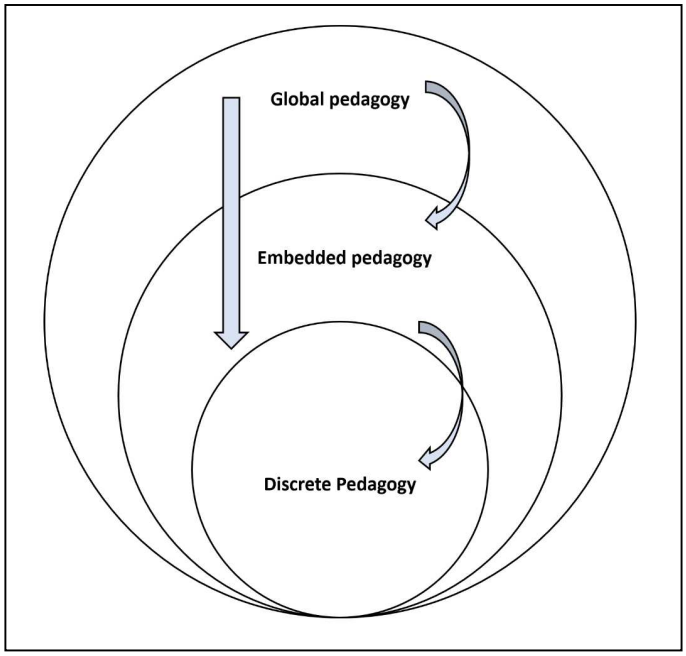

Figure 2: A visual categorization of nested learning pedagogies that emerged from the review

Table 2 below summarizes the findings and the character education pedagogies as defined by this nested framework. As noted, most studies applied pedagogies in combination. Twenty-four of the 30 studies were structured around the global pedagogy of either Case Based Learning, Project Based Learning, Service Learning or some combination of these three pedagogies. In 12 of the 30 studies, there were also embedded pedagogies in place to support ongoing learning experiences namely collaborative learning and technology enhanced learning either within the broader context of a global pedagogy or otherwise. Global and/or embedded pedagogies often incorporated discrete pedagogies such as reflections (written), discussion and/or lecture. In a few cases, these discrete pedagogies were applied in isolation, with other discrete pedagogies or nested within the broader context of embedded and/or global pedagogies.

TABLE 2: SUMMARY OF PEDAGOGICAL APPROACHES DESCRIBED IN THE FINAL LIST OF SELECTED REFERENCES

Index	Author(s)	Year	Title	Intervention/ Proposed Intervention (I/PI)*	Summary of Pedagogies			Virtues/Character Focus
					Global Pedagogy	Embedded Pedagogy	Discrete Pedagogy	
1.	Carpenter et al.	2015	Assessing the Ethical Development of Students in an Undergraduate Civil Engineering Course Using a Standardized Instrument	I	Case Based Learning	Collaborative learning	Reflection, Interview, Discussion	Virtues broadly construed/virtue ethics among other ethical frameworks
2.	Davis and Butkus	2008	A Study in Engineering and Military Ethic	I	Case Based Learning		Reflection Discussion	Moral character development broadly construed
3.	de la Riva de la Riva et al.	2015	Sustainability in engineering education: an approach to reach significant learning and character skills	I			Lecture Discussion Other	Character development broadly construed
4.	Dillon et al.	2020	Students Taking Action on Engineering Ethics	I	Project Based Learning	Collaborative learning	Other	Ethics and character broadly construed
5.	Fleischmann and Shirley	2001	Abet 2000 And Community Service Projects for Engineering Students	I	Service learning, Project Based Learning	Collaborative learning	Reflection, Discussion	Character development broadly construed
6.	Frankman et al.	2007	Training Internationally Responsible Engineers	I	Service Learning, Project Based Learning			Character development broadly construed
7.	Frigo et al.	2021	Training responsible engineers. Phronesis and the role of virtues in teaching engineering ethics	PI	Project Based Learning, Case Based Learning		Reflection Lecture, Discussion	Phronesis (practical wisdom)
8.	Golding, Peter et al.	2018	Growing Character Strengths Across Boundaries	I		Technology enhanced learning	Reflection	Willpower, self-control and grittiness
9.	Gomez et al.	2013	To be Green or Not to Be Green? Ethical Tools for Sustainable Engineering	I	Project Based Learning		Discussion Role Playing	Virtue ethics (among other ethical frameworks)
10.	Gross, Michael et al.	2021	The Virtues of Teamwork: A Course Module to Cultivate the Virtuous Team Worker	I	Project Based Learning			Teamwork
11.	Hawks, Val	2009	Teaching Leadership Principles to Undergraduate Engineering and Technology Students	I	Project based learning, Case Based Learning	Collaborative learning	Discussion	Character development
12.	Henslee et al.	2021	ETHICS-2021 Special Session 7: Integrating virtue ethics into STEM courses	I			Discussion Other	Virtue ethics (practical wisdom, intellectual humility and empathy)
13.	Hilyana and Hakim	2018	Integrating character education on physics courses with schoology-based e-learning	I		Technology enhanced learning	Other	Character indicators of accountability, nationalism, public ethics, quality commitment and anti-corruption
14.	Jen et al.	2012	Teaching Entrepreneurship Through Virtues	I		Collaborative learning	Lecture	Creativity, diligence, wisdom
15.	Jordan et al.	2003	Using Moral Theories to Help Engineers Make Ethical Decisions	PI	Case Based Learning			Virtue ethics
16.	Jordan, W.	2006	A virtue ethics approach to engineering ethics	PI	Case Based Learning			Virtue ethics
17.	Kenny et al.	2021	Infusing the Liberal Arts in First-Year Engineering: A Module on History, Professional Identity, and Courage	I		Collaborative learning	Reflection Lecture	Courage

18.	Krones et al.	2021	An Integrated Engineering/History/Ethics First-year Experience at Boston College	I	Case Based Learning	Collaborative learning	Discussion Other	Virtue ethics
19.	Moriarty, G.	2006	The ethics engine: A mathematical approach for motivating engineering ethics discussion	PI	Case Based Learning		Discussion	Virtue ethics (among other ethical frameworks)
20.	Nordin and Barton	2021	Teaching Ethical Theory and Practice to Engineering Students: Pre-pandemic and Post-pandemic Approaches	I	Case Based Learning	Collaborative learning	Lecture, Discussion	Virtue ethics (among other ethical frameworks)
21.	Pierrakos et al.	2019	Reimagining Engineering Ethics: From Ethics Education to Character Education	PI	Case Based Learning			Intellectual humility, practical wisdom, courage, honesty, patience, diligence and inclusion
22.	Riley, D. M.	2015	Pushing the boundaries of Mass and Energy: Sustainability and social Justice Integration in Core Engineering Science Courses	I	Project Based Learning		Reflection	Virtue ethics (among other ethical frameworks)
23.	Stone et al.	2020	Before responsible innovation: Teaching anticipation as a competency for engineers	PI	Case Based Learning	Collaborative learning	Reflection Lecture Discussion	Moral sensitivity, epistemic humility and moral imagination
24.	Summet and Bates	2020	Science Fiction as an Entry Point for Ethical Frameworks in Engineering and Computer Science Education	I	Case Based Learning		Discussion	Virtue ethics among other ethical frameworks
25.	Susanto et al.	2022	The Product Development of Portable Laboratory Integrated with Local Wisdom (PL-ILW) by Undergraduate Student	I	Project Based Learning		Lecture	Character development (broadly construed)/local wisdom
26.	Van Tyne, N.C.T.	2020	Work in Progress: How Should We Decide? The Application of Ethical Reasoning to Decision Making in Difficult Cases	I	Case Based Learning		Other	Virtue ethics among other ethical frameworks
27.	Van Tyne, N.C.T.	2020	GIFT: The Influence of Stakeholders in Ethical Decision Making	I	Case Based Learning			Virtue ethics among other ethical frameworks
28.	Warford, E.L.	2016	Ethics in the Classroom: The Volkswagen Diesel Scandal	I	Case Based Learning		Reflections Lecture	Virtue ethics among other ethical frameworks
29.	Wilson, R.L.	2021	Anticipatory Ethics as a Method for Teaching Engineering Ethics	I	Case Based Learning			Virtue ethics among other ethical frameworks
30.	Wylie and Neeley	2016	Learning Out Loud (LOL): How Comics Can Develop the Communication and Critical Thinking Abilities of Engineering Students	I	Case Based Learning		Discussion Lecture	Virtue ethics among other ethical frameworks; critical thinking

*Indicates whether the study was of an existing intervention or a proposed intervention

1.1. Global Pedagogy - Case Based Learning

Case based learning (CBL) (also known as case based teaching or case based instruction) is a student centered approach that uses case studies, narratives of real-life experiences, or carefully crafted hypothetical situations to help students explore the complexities of professional engineering that may include technical and contextual details and motivate decision making processes and which include unstructured solutions to problems [21], [22]. It is one of the most commonly used teaching strategies in engineering ethics education [8], [23]. Successful CBL encourages students to develop expertise by simulating real experiences that challenge their thinking but in a controlled environment, where the stakes of the real environment are absent or lessened. Sometimes case studies are nested within problem based learning, as student teams are challenged to confront, embody and often draw inspiration from historical disasters or remarkable innovations as they address authentic problems [24].

Seventeen out of the 30 character references identified involved case based learning [6], [7], [20], [25]–[38]. In several examples, analysis of the cases was preceded by a priming of ethical frameworks, of which virtue ethics was one of the frameworks [20], [25], [27], [29]. Case studies analysis involved open ended discussions [37] or guided discussions facilitated by prompts or instructions [29], [39], role playing exercises in which students took the perspective of different stakeholders [28], [37] as well as collaboration in teams [20], [25], [29], [34].

Notably, Summet and Bates [39] described an ethics module based on science fiction which we have included here as case based learning. The module involves fictional stories intended to draw students' attention to ethical dilemmas followed by targeted questions to facilitate discussion. Even though the term case study is not used to describe these stories by the authors, they closely resemble hypothetical cases and have been placed in this section.

1.2. Global Pedagogy - Project Based Learning

In Project Based Learning (PBL), students are assigned a task that leads to the creation of a final product such as a device, a model, or a computer simulation [22]. Projects may vary in scope, duration, structure, degree of student autonomy, and other factors. Based on our review, several character based interventions applied PBL [6], [33], [34], [40]–[45]. Majority of the projects were team-based experiences. Sometimes the projects were directly used to address issues around ethics and character [40]. In other cases, the project provided an environment for modules to support character development [6], [43]. For instance, Gross et al. [42] described a first-year core engineering course in which students engaged in two six-weeklong projects over the course of a semester. A module dedicated to cultivating teamwork was embedded between the end of the first project and the beginning of the second project, which applied the seven strategies of character development [19].

1.3. Global Pedaogy - Service learning

Service Learning is characterized by students enrolling in a course for credit while simultaneously addressing the need of a community and engaging in a process of reflection upon the experience [46]. While Service Learning and PBL are not exactly the same, Service Learning can be considered a sub-type of PBL. Two reviewed projects described project based interventions geared towards serving the needs of a community [33], [41].

2.1. Embedded Pedagogy - Technology Enhanced Learning

Interestingly, two character education interventions that emerged involved the use of technology to support students' character based learning and development. Notably, Hilyana & Hakim [47] reported about Schoology, a platform that combines features of a learning management system and social media, which was used to convey physics related content to electrical engineering students and simultaneously support character development. The system was infused with character education operationalized by indicators of a model called ANEKA, which are: accountability, nationalism, public ethics, quality commitment and anti-corruption. Students participated in trainings using this online platform. The ANEKA values were written into their lesson plan and the platform created an avenue for students to continue learning independently. Even though the integration of the electricity concepts with ANEKA character indicators was unclear as well as what working online looked like with both components, it was still interesting to see the central role that technology played. Similarly, Golding et al. [48] discussed a cloud based app, EduGuide, for online mentoring and activities with an effort to grow strength in character, especially grit, in students. The online toolset involves life lessons and facilitates communication for mentoring students and growing their awareness and mindset. More specifically, students used the technology to complete learning activities followed by feedback from their teacher or other faculty, staff and peer guides that support them with mentoring responses that would spark further engagement in writing and reflection.

2.2. Embedded Pedagogy - Collaborative Learning

Collaborative learning refers to an approach in which students work in teams to achieve a common goal (Prince, 2004). It is an environment that affords the social construction of knowledge among students [50]. This pedagogical approach supports students' overall learning, development of communication and social skills and their ability to work in teams [50], [51]. Several implementations of character education applied collaborative learning [27], [34], [40], [41], [43], [52]. Collaborative learning was applied more specifically by involving students in competition [52], projects [34], [40], analysis of ethics cases sometimes accompanied by a written essay, oral presentation and/or discussions [6], [20], [26], [32], [41], [52], [53].

3.1 Discrete Pedagogy - Discussion

Discussion is one of the most used pedagogies for ethics education [8]. The use of discussion appeared in ten of the thirty results [6], [20], [41]–[43], [52], [54], [25], [26], [31], [32], [35], [37]–[39]. All but one [55] used discussion in the context of Case Based or Project Based Learning. In most examples, students were encouraged to engage in discussion about ethical case studies [6], [20], [25], [38]. Sometimes the discussions were about current events/contemporary issues (Davis &

Butkus, 2008). In some others, specific artifacts like various pieces of media created by students [54], comics [31] or prompts [39] were used to spark discussion in the classroom.

3.2 Discrete Pedagogy – Lectures

Lectures were used as a priming mechanism [56], [26], [6], [53], [33], [45], [29], [38]. Sometimes they were used to introduce ethical frameworks and in other examples, they were used to address technical aspects of projects integrated with character development [45]. Some of the lectures were discussed as those taught by faculty while others were guest lectures including those by engineers [6], [53] or speakers from other disciplines like history [53] to engage students with the real world practice of engineering.

3.3 Discrete Pedagogy - Reflection

Six interventions involved written reflections [20], [25], [41], [6], [52], [53], [33]. These reflections ranged from short responses to prompts in a learning management system to more elaborate papers.

3.4 Other Discrete Pedagogies – Role Play, Debate and Unique assignments

There were other discrete pedagogies that did not fit our classification or occur enough times to warrant their own section but are worth mentioning for their importance. They include role play, debate and unique activities and assignments. These will be described using concrete examples.

Krones, Tonn and Powell [30] described a course that implemented a case study approach with cases analyzed in a variety of ways. The historical case of the Boeing 737 Max disaster involved students *role playing* different stakeholders and engage in *debate* about their responsibilities and decisions based on their stakeholder roles. Another one of their examples involved students assigned a specific case of a chemical spill or disaster as a group after which they analyzed the case together and defended their analysis in a presentation to the class (*unique assignment*).

In addition to this class presentation, students have also shared their analysis of case studies through other unique assignments like written essays [27]. Similarly, the character program described by de la riva de la riva and colleagues [56] involved students writing essays in response to watching a movie.

Another unique assignment involves student creating pieces of media (e.g. infographics, videos or short story plots) about an assigned topic related to artificial intelligence (AI) such as AI employment, AI humanity and AI bias which were submitted by students and used to lead weekly discussions both online and in class [54].

In some cases, it was evident that some discrete learning activities were applied to support students' learning and character development however, with insufficient detail to allow these activities to be labelled.

IV. DISCUSSION OF FINDINGS

Our findings show that while character education is still emerging in engineering education, existing efforts have utilized approaches that are part of the existing toolkit for teaching technical content and are therefore accessible to most educators. There are, however, many opportunities for improvement and productive growth, particularly in the areas of effective interventional design and assessment. Most of the interventions we reviewed did not include formal assessments to gauge impact on student learning and even fewer followed a formal interventional protocol.

One key observation is that most efforts to cultivate character have been student-centered, meaning they compel students to take increased personal responsibility for their own learning [22]. This observation supports the recent finding that virtue education in engineering tends to involve student centered pedagogical approaches [13]. Student centered approaches help students come to the understanding of essential concepts on their own terms by engaging targeted challenges [22]. Gaining new knowledge in this manner can facilitate intrinsic motivation and improved self-efficacy [13], [57], [58]. Distinctions between individual and team-based interventions also emerged. Efforts rooted in Project Based Learning were typically team based with an embedded collaborative learning framework. Case based strategies, on the other hand, provided more opportunities for individual character development that does not rely on peer interactions. The relative costs and benefits of learning character alone versus in a group have not been studied but represent fertile ground for future research.

In many cases, character education played an ancillary role within a broader pedagogical effort. Ethical decision-making or virtuous action are embedded within lessons that convey foundational technical knowledge. We might expect that assigning character supporting, rather than starring, roles in course activities would reduce educational impact, emerging evidence from our own program indicates that many engineering students may strongly prefer the embedded approach and perceive character-centric curricula as juvenile or uninspiring.

Finally, it is important to remember that all efforts reviewed herein are from undergraduate engineering. Character education literature and associated insight from other fields, STEAM and otherwise, could provide substantial additional insight. Character-focused learning differences among various student populations are beginning to emerge [59], but there are also certainly significant areas of commonality that can drive interdisciplinary insight.

V. IMPLICATIONS

The findings of this study show that there are a variety of approaches used to incorporate character in the engineering curriculum that to some degree address the challenges we identified at the beginning of this paper. Because the pedagogies commonly used are to a large extent student centered, there is hope that implementations of character education in undergraduate engineering can be engaging to students based on what we know about student centered approaches generally. However, assessment of these approaches specific to the objectives of character interventions would provide clearer evidence of their efficacy.

Additionally, the eight major pedagogies that emerged from this study are familiar in engineering education and the references here provide some examples that could promote their further use

to support student's character development and ethical decision making processes. Beyond their familiarity, they have also been implemented in a variety of ways (e.g. embedded in semester long projects, incorporated into small modules within a course or used in an assignment) which provides encouragement that faculty could apply them in the ways and scope that work best for their context. Even with rigorous and condensed engineering curricula, character interventions can be integrated authentically into existing courses that help students better connect their technical knowledge with contextual details that support character driven practice of engineering.

Lastly, the findings show that with some intentionality, we can bring to the forefront moral and more holistic dimensions of character in engineering. This intentionality could be as explicit as introducing moral theories to students as a framing for further character and ethics based activities or through more implicit approaches such as inviting contemporary topics in the classroom that motivate character driven thinking, discussion and action.

VI. LIMITATIONS

The primary limitations of this study are (1) there is not a shared vocabulary or taxonomy of character in engineering, so we recognize that our search terms of "character education" "character development" and "virtues" may not have generated all relevant results, (2) character education in engineering is nascent, and much of what exists may still be unpublished, and (3) the search results were more of an exposition of the work being done at the intersection of character education and undergraduate engineering, but very few had been evaluated, so we can only infer how effectively students were engaged, the accessibility for faculty, and how well they integrated with technical content, and to what extent the moral dimension was covered as opposed to skills (all of our problems that we are trying to solve).

VII. FUTURE WORK

This high-level review represents the first steps of a much broader effort. Future work should examine the effectiveness of specific pedagogies for engaging students. This review has focused on identifying the nature of existing character education pedagogies and to some degree, how they have been applied. It is important to also know the degree to which they have engaged and educated students. The more engaged students are with their learning, the more likely they are to experience change (for a recent review, see [61]. This need to better understand effectiveness in engaging students and promoting change also reveals a need to further examine how programs have assessed character-based interventions. Successful assessments would seek to understand how effective these interventions are at helping students, and ultimately professional graduates, navigate ethical issues and make character-focused decisions.

Assessing character development is particularly challenging because character is nearly impossible to observe until it is displayed through action, and even then, underlying motivational forces are complex. Further, it will be important to use character assessments in ways that value honesty but avoid demotivating students. For instance, a student could be demoralized to hear "you are rated low on empathy" or "your results suggest you are not a very honest person", but on the other hand, shouldn't they have access to their data and the apparent insights within? As character education at the post-secondary level gains momentum, this will be a difficult path for educators to successfully navigate.

Some of the papers we examined mentioned character development from the perspective of art, and because it was unclear whether there was an objective of promoting students' character development in the process, we excluded them. However, we think this area is worth exploring further. Character development in art deals with a fictional character's development with all the kinds of complexities that could occur in real life. They involve techniques such as role play, storytelling and writing in which students connect with the character [56], [61], [62]. Consequently, we think the art of character development is an interesting avenue to foster the appreciation and development of morality and therefore represents an innovative opportunity for engineering educators.

VIII. CONCLUSIONS

We conducted a scoping literature review and identified a complementary set of pedagogical approaches used in undergraduate engineering education to support character education. . Most of these pedagogies are commonly used to teach core engineering concepts, while others are more innovative, drawing from disciplines such as the arts and humanities. In most cases, character education efforts involved a combination of nested pedagogical approaches to support student engagement, such as Project Based Learning embedded with lecture, reflection and discussions.

Based on the challenges we experienced in finding character education efforts, we suggest that there is a need for a more shared understanding on what character education entails in the engineering education context. We chose to focus on efforts that used the language of character, virtues, and virtue ethics for the purposes of this study, but this approach invites some important questions. Are these terms commonly understood in the engineering education community? What meanings do these terms convey to engineers? Do these meanings support the broader goal of developing engineers who are morally and ethically responsible?

Moving forward, character education in engineering education must continue to evolve , drawing perspective and insight from growing bodies of disciplinary and interdisciplinary literature. For instance, while Case Based Learning is familiar to the engineering education community, it is important to integrate innovative ways to help students authentically engage cases and, connect with the realities they will face as professionals, and get motivated to showcase their ethical judgment and sense of morality.

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APPENDIX. SUMMARY OF SCOPING ITERATIONS

The initial search used variations of the search terms “character education”, “character development”, “virtues”, “engineering” and “engineering education”. Based on discussions about the results (see Table 3) and search terms, we conducted a series of searches this time keeping the search terms consistent across all databases. A crucial part of this dialogue was that we revisited our research question to agree upon what should count as “character education efforts”. This led to consensus that if an engineering education effort takes a virtue ethics lens to an ethics intervention, that was indeed a part of character education. What made this conversation particularly important such that it motivated further investigation is that we did not want to overlook meaningful implementations of character education centered around virtue ethics that previous attempts might have missed.

Additionally, there were unique qualities of the databases used that created variable results. For instance, ASEE PEER presented the challenge that we could not select the most relevant search results on the website before exporting them into a spreadsheet. Consequently, it was important to refine our searches on this database as much as possible to get the most relevant results to avoid going through a large spreadsheet of distantly related search results. In another instance, we had only one result presented in IEEE Xplore which we were skeptical about given that we had previously seen more than that number of relevant titles based on previous searches. These instances exemplify some of the reasoning behind our iterations.

These iterations involved some important details unique to each database. In IEEE Xplore we searched within “all Metadata”, for Scopus we searched within “Article title, Abstract, Keywords” and for ASEE PEER, we disregarded the + - symbols suggested in the instructions on the website (due to overwhelming results in the thousands, during some of the searches, that the + symbol produced) and used “OR” and “AND” for modifying the search terms as was done for other databases. In all databases, search words were in parentheses where we wanted exact keywords.

TABLE 3. INITIAL SEARCH TERMS AND RESULTS

Database	Search Terms	Initial Results
ASEE PEER	“Character education” + “character development” + “virtues”	4
IEEE Xplore (from 2011)	"Character education" OR "character development" OR "virtues" and "engineering"	136
Scopus (from 2011)	“Character education” OR “character development” OR “virtues” and “engineering education” (due to broader database)	465

TABLE 4. SUMMARY OF REPORTS FROM THE SEARCH TERMS, "CHARACTER EDUCATION" OR "CHARACTER DEVELOPMENT" AND ENGINEERING EDUCATION

Index	Author(s)	Year	Title
1.	Carpenter et al.	2015	Assessing the Ethical Development of Students in an Undergraduate Civil Engineering Course Using a Standardized Instrument
2.	Donald et al.	2020	Using a structured approach to reflective journaling in engineering leadership development
3.	Eddelson et al.	2021	Integration of Ethics-Focused Modules into the Steps of the Engineering Design Process
4.	Eggleston and Rabb	2021	Leader development model (LDM) through self and peer assessment across the curriculum
5.	Gerhart et al.	2014	Combining Discipline-Specific Introduction to Engineering Courses into a Single Multidiscipline Course to Foster the Entrepreneurial Mindset with Entrepreneurially Minded Learning
6.	Gomez et al.	2013	To be Green or Not to Be Green? Ethical Tools for Sustainable Engineering
7.	Gross et al.	2021	The Virtues of Teamwork: A Course Module to Cultivate the Virtuous Team Worker
8.	Henslee et al.	2021	ETHICS-2021 Special Session 7: Integrating virtue ethics into STEM courses
9.	Hilyana and Hakim	2018	Integrating character education on physics courses with schoology-based e-learning
10.	Jordan and Napper	2003	Using Moral Theories to Help Engineers Make Ethical Decisions
11.	Jordan, W.	2006	A virtue ethics approach to engineering ethics
12.	Krishnamurthy	2017	Teaching Engineering Ethics in Asia from Western Resources
13.	Krones et al.	2021	Full Paper: An Integrated Engineering/History/Ethics First-year Experience at Boston College
14.	Moriarty, G.	2006	The ethics engine: A mathematical approach for motivating engineering ethics discussion
15.	Nordin and Barton	2021	Teaching Ethical Theory and Practice to Engineering Students: Pre-pandemic and Post-pandemic Approaches

16.	Pierrakos et al.	2019	Reimagining Engineering Ethics: From Ethics Education to Character Education
17.	Riley, D. M.	2015	Pushing the boundaries of Mass and Energy: Sustainability and social Justice Integration in Core Engineering Science Courses
18.	Stone et al.	2020	Before responsible innovation: Teaching anticipation as a competency for engineers
19.	Summet and Bates	2020	Science Fiction as an Entry Point for Ethical Frameworks in Engineering and Computer Science Education
20.	Susanto et al.	2022	The Product Development of Portable Laboratory Integrated with Local Wisdom (PL-ILW) by Undergraduate Student
21.	Van Tyne, N.C.T.	2020	Work in Progress: How Should We Decide? The Application of Ethical Reasoning to Decision Making in Difficult Cases
22.	Van Tyne, N.C.T.	2020	GIFT: The Influence of Stakeholders in Ethical Decision Making
23.	Warford, E.L.	2016	Ethics in the Classroom: The Volkswagen Diesel Scandal
24.	Wilson, R.L.	2021	Anticipatory Ethics as a Method for Teaching Engineering Ethics
25.	Wylie and Neeley	2016	Learning Out Loud (LOL): How Comics Can Develop the Communication and Critical Thinking Abilities of Engineering Students

TABLE 5. SUMMARY OF REPORTS FROM THE SEARCH TERMS, "CHARACTER EDUCATION" OR "CHARACTER DEVELOPMENT" OR "VIRTUE ETHICS" AND "ENGINEERING EDUCATION"

Index	Author(s)	Year	Title
1.	Carpenter et al.	2015	Assessing the Ethical Development of Students in an Undergraduate Civil Engineering Course Using a Standardized Instrument
2.	Donald et al.	2020	Using a structured approach to reflective journaling in engineering leadership development
3.	Eddelson et al.	2021	Integration of Ethics-Focused Modules into the Steps of the Engineering Design Process
4.	Eggleston and Rabb	2021	Leader development model (LDM) through self and peer assessment across the curriculum
5.	Gerhart et al.	2014	Combining Discipline-Specific Introduction to Engineering Courses into a Single Multidiscipline Course to Foster the Entrepreneurial Mindset with Entrepreneurially Minded Learning
6.	Gomez et al.	2013	To be Green or Not to Be Green? Ethical Tools for Sustainable Engineering
7.	Gross et al.	2021	The Virtues of Teamwork: A Course Module to Cultivate the Virtuous Team Worker
8.	Henslee et al.	2021	ETHICS-2021 Special Session 7: Integrating virtue ethics into STEM courses
9.	Hilyana and Hakim	2018	Integrating character education on physics courses with schoology-based e-learning
10.	Jordan et al.	2003	Using Moral Theories to Help Engineers Make Ethical Decisions
11.	Jordan, W.	2006	A virtue ethics approach to engineering ethics
12.	Krishnamurthy	2017	Teaching Engineering Ethics in Asia from Western Resources
13.	Krones et al.	2021	Full Paper: An Integrated Engineering/History/Ethics First-year Experience at Boston College
14.	Moriarty, G.	2006	The ethics engine: A mathematical approach for motivating engineering ethics discussion
15.	Nordin and Barton	2021	Teaching Ethical Theory and Practice to Engineering Students: Pre-pandemic and Post-pandemic Approaches
16.	Pierrakos et al.	2019	Reimagining Engineering Ethics: From Ethics Education to Character Education
17.	Riley, D. M.	2015	Pushing the boundaries of Mass and Energy: Sustainability and social Justice Integration in Core Engineering Science Courses
18.	Stone et al.	2020	Before responsible innovation: Teaching anticipation as a competency for engineers
19.	Summet and Bates	2020	Science Fiction as an Entry Point for Ethical Frameworks in Engineering and Computer Science Education
20.	Susanto et al.	2022	The Product Development of Portable Laboratory Integrated with Local Wisdom (PL-ILW) by Undergraduate Student
21.	Van Tyne, N.C.T.	2020	Work in Progress: How Should We Decide? The Application of Ethical Reasoning to Decision Making in Difficult Cases
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24.	Wilson, R.L.	2021	Anticipatory Ethics as a Method for Teaching Engineering Ethics
25.	Wylie and Neeley	2016	Learning Out Loud (LOL): How Comics Can Develop the Communication and Critical Thinking Abilities of Engineering Students