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Identifying Core Engineering Virtues: Relating Competency and vVrtue to Professional Codes of Ethics

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Abstract

This work focuses on a single question: "Which virtues ought to be emphasized in the formation of engineering and computing professionals?" The authors assume that the ethical codes proposed and maintained by various engineering and computing (E/C) professional bodies represent reasonable assertions as to the types of ethical considerations expected of E/C professionals. It then attempts to bridge what the profession(s) assert to be good (e.g., within the various codes of ethics) to observable virtues/dispositions that can be connected to student formation. This work lays out the case for connecting virtue to competency, presents a collection of operational definitions for various virtues and explores a collection of engineering and computing codes of ethics as a means of identifying virtues more necessary to engineering and computing competence. Thereupon, this work proposes four virtues as more essential to the E/C professional: Prudence, disinterestedness, truthfulness, and justice.

Introduction

Virtue focuses on the morally good, or as Julia Annas describes it, "A virtue is a lasting feature of a person, a tendency for the person to be a certain way." [1] This matters significantly in engineering and computing. For example, the virtue of prudence is shown by the engineering/computing (E/C) professional who routinely tests their work to ensure its quality. Conversely, the E/C professional who does not bother to adequately test their work fails to show prudence; in that sense they may be reasonably accused of failing to act as a competent E/C professional. The question is, among many virtues, what virtues are more (or most) critical to an E/C professional? This work supposes that established codes of ethics are sources from which to explore answers useful to E/C educators.

Essential to the exploration of E/C virtue in is a three-fold distinction that is often confused in the engineering tradition: Distinguishing among the *goodness of engineering* as it is conducted, the *goodness of the engineering product*, and the *goodness of the engineer* conceiving, designing, implementing and/or making operational the product. When considered *in toto*, having this (or any) marker for goodness provides a bridge between ethics and the actual business of professionally-conducted engineering, and consequently the development of a competent, professional E/C professional.

Competence, at some level is always our judgment on the values that we expect of the engineer, reflected through how they go about engineering. In essence they are a reflection on the goodness of the engineer, yet these are always judged in the context of the state of the art, meaning the goodness of the engineering process applied. But it is in the choices of the engineers themselves that the connection between the goodness of the engineering and the goodness of the engineer meet. This happens through agency, where the person reflects the values of the engineering and computing profession in how they accomplish, how they apply good engineering. *E.g.*, these values are always reflected through the agency of the E/C professional.

Herein lies the connection between the nature of competency as learned/developed in engineering and computing degree programs[2]–[6], and what is termed 'virtue ethics' [1], [7], [8]. The two key concepts that connect these explorations are *disposition* [9] and *action* (agency). While there have been several efforts in identifying dispositions useful for expressing E/C competency statements [4], [5], [9], this effort takes a different approach. Rather, we explore what dispositions aiming at the good (virtues) appear more essential in E/C education given the professions' various statements of professional ethics. This relationship between virtue ethics and competency impacts both the nature of what effective engineering and computing education should look like. Identifying which virtues (dispositions aimed toward the good) are most relevant can then serve as points of observation about how the good asserted by the profession (embodied in codes of ethics) is both taught in E/C programs and embraced by E/C students and professionals.

Virtue Ethics

Virtue ethics emphasize the nature and definition of virtues and often focus on the consequences of actions; to possess a virtue is to be a certain sort of person with a certain complex mindset [7], [10], [11]. Virtue encompasses the motives, the powers, the actions, and the being of a person gathered into a characteristic whole by a definitive moral value [12]. Virtue is not determined by singular action, but rather by a pattern. While drawing deeply from a long history of philosophy, Annas provides a dispositional account of virtue in relation to the agent, the person: A virtue is a disposition of character to act reliably, not a passing mood or an attitude. Nor is it just a trait or a mere disposition to perform acts that have been independently labelled as virtuous. Further, a disposition has to be acquired by habituation, but a virtue is not a matter of being habituated to routine. It expresses the kind of habituation that a skill does, one in which the agent becomes more intelligent in performance rather than routinized. [1]

The missing component in this discussion is the understanding of 'good', of the essential connection to the ethic desired in E/C education. This includes identifying the criteria by which goodness is established for E/C education in general, and/or the criteria for goodness for an E/C program in particular. Moral goodness has at least two aspects: obligations and virtues. The obligations of morality arise for us because we live among others of approximately equal strength and vulnerability[1], or perhaps determined by the minimal rules a human community needs to enforce for some good. For E/C, this is one means of interpreting the various Codes of Ethics, as obligations imposed by the community of E/C professionals. However, stripped of other connections, obligation provides a weak impact on forming students with a desire to do and be good. [13]–[15]

Here is where virtue provides a richer, more human side to the goodness equation, for what counts as a virtue can depend upon characteristics or circumstances which are not universal [16]; Consequently the list of virtues will not be the same for all, leaving open the legitimate question as to which virtues are most important/needed for E/C professionals and those students who approach E/C education with that goal. Exploring and understanding the criteria for goodness is

[1] See G.H. von Wright, *The Varieties of Goodness*, as quoted in [14].

essential to this exercise. One could consider, as Aristotle would put it, the thing's *ergon* (what it does), or in this case what the E/C student does, and certainly this should include the different kinds of goodness suitable to this student/soon-to-be graduate [14]. When examining goodness as reflected in practice, an important meaning of 'good' encompasses moral responsibility, serving others and making an authentic contribution to society [17].

In this sense, A virtue is a disposition which is central to the person, to whom s/he is, often referred to as character and are expressed through their acting, reasoning, and feeling in certain ways. [1] Similarly not all dispositions are virtues; attention to detail is an example relevant to E/C education: Is the application of attention to detail always good? Again the answer is 'no'; there are numbers of situations where attention to detail is counterproductive, and others where it is essential. [5], [9] This emphasis on 'disposition of character' is critical to understanding the relationships among topics central to engineering education. But rather than connecting to the body of knowledge privy to a specific E/C discipline, disposition plays a more central role in the development of competency [4], [6], the means by which the knowledge and skills of a particular E/C discipline are enacted.

Relating Ethics and Competency

At issue in E/C Education has been a two-fold challenge: The challenge of assessing students as developing professional engineers (*e.g.*, "The Competency Problem") [18]–[20] and the challenge of forming students as ethical practitioner (*e.g.*, "The Ethics Problem") [15], [21]–[23]. This exploration focuses on one particular aspect of these broad problems: Connecting ethics and competency for the purpose of better framing the educational goals expected of E/C educational programs.

Ethics are well-founded standards of right and wrong that prescribe what humans ought to do, usually in terms of rights, obligations, benefits to society, fairness or specific virtues.[2] Normatively, ethics are framed around E/C as it is conducted, around the E/C product, its use(s), and around the E/C professional doing the work. When applied (beyond the cognitive recognition), ethics connect what is deemed as 'good' to the actor, seen through the good (or virtuous) actions of the actor. [14]

Competency in E/C Education

In 2018, Frezza *et al* published the CoLeaF framework for modelling competency as an educational goal for E/C education [6]. CoLeaF models competency as the combination of knowledge, skills and dispositions expressed in a context. This model captures an essential aspect of learning, in that now the goal of a learning includes not just cognitive topics or skills, rather it includes affective components related to the actions of the students enacted in the context in which the particular E/C competency is observed [5], [9]. Again, the emphasis is on the observation of competency in the student. Consequently, observing the pattern of actions (agency) as means of assessing a particular competency of a particular E/C student, reflecting disposition development that links the various E/C knowledge and skills to appropriate action [9].

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[2] See Manuel G. Velasquez, *Business Ethics Concepts and Cases* as cited in [17].

Work in competency theory [6] connects disposition to E/C knowledge and skills expected of the E/C graduate. Here a particular competency, as with virtue, is always observed behavior: something viewed in the actions of the student, enacted in a particular context. This provides a similar connectivity as with applied ethics. Figure 1 presents a simplified version of this relational model, illustrating the parallel between these approaches: Both enacted ethics and competency have an expectation that the student's (actor's) actions are observed, and through their agency they reflect (hopefully) 'good' conduct of the engineering work, in the engineering of 'good' E/C products by 'good' E/C students.

The connection of actor & actions (agency) and the relationship of virtue & dispositions suggests that the 'good', as framed by professional engineering ethics, are integral to competent engineering behavior. Developing 'good' E/C competency implies formation in not just the knowledge of, but rather the practice of E/C ethics.

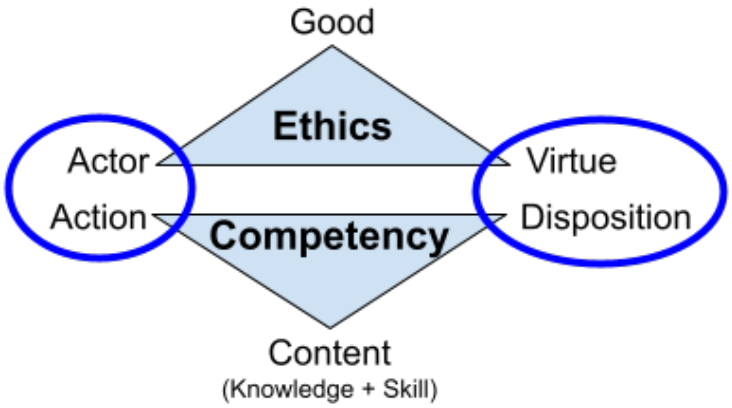

Figure 1. Connecting Competency and Ethics through enacted virtue

With the assumption that E/C programs have the 'good' of the relevant professional ethics as their goal (*e.g.*, ABET Criteria 4 "an ability to recognize ethical and professional responsibilities in engineering situations...") the relationships depicted in Figure 1 suggests that the connection between 'good' of E/C activity and the student can be assessed through the lens of competency. However, the implications are deeper: E/C professional ethics are encoded in the codes of ethics [22]. This also suggests that E/C codes of ethics can, if reviewed through the lens of virtue, provide a minimal list of E/C virtues (dispositions) that are minimally needed in E/C programs. Similarly, these virtues/dispositions frame our case for developing particular engineering core values and dispositions as a means of bridging ethical standards and providing the ability to make the relevant virtues/dispositions observable through engineering and computing competency development [5]. The focus of this paper is on the first of these goals, identifying core values (virtues) through the lens of published E/C professional ethics.

At issue in any effort to codify values for education is the identification of the language with which to express that meaning; for example, in formulating competency statements, what language to use to express knowledge, skill and/or disposition [4], [5], [9]. In particular, dispositional language plays a significant role in expressing the expectations and goals of student

learning with respect to competency. While these expressions of meaning are necessarily culturally and temporally located, we provide a brief introduction to a set of virtues suitable for identifying core E/C values.

Connecting Virtues

Virtues necessarily touch upon other virtues; in this sense, it is difficult to consider any virtue by itself, or as a strict rule. As understood by writers like Thomas Aquinas, every virtue includes a consciousness of its prudential employment [12], [16][24]. Virtue has been a component of philosophical and ethical thought for millennia. While the virtues valued in particular societies are both temporally and culturally located, the Greek philosophers of antiquity and numerous contributors throughout the centuries have developed well-used lists of virtues. While a full treatment of virtue as a study in philosophy and ethics is well beyond the scope of this work, Table 1 presents a selection of moral virtues presented by major authors including Aristotle (d. 322 BC), Gregory I (d. 590 AD), Thomas Aquinas (d. 1274 AD), Romano Guardini (d. 1963) and a list compiled by the Jubilee Centre for Character Development [25]. While necessarily inexact, these have been roughly organized using the "Cardinal Virtues" of *Prudence*, *Justice*, *Fortitude* and *Temperance* (or moderation) proposed by Aquinas and others in the Middle Ages.

Table 1. Selections of Moral Virtues

Aristotle (322 BC)	**Gregory I (590 AD)**	**Thomas Aquinas (1274 AD)**		**Romano Guardini (1963)**	**Jubilee Centre (2015)**
		Prudence	Memory Docility Shrewdness Reasoning Foresight Circumspection Caution	Acceptance Understanding Disinterested-ness	Integrity
Liberality Wittiness	Charity	Justice	Religion Piety Liberality Affability Gratitude	Reverence Recollection Justice Loyalty Justice Before God Gratitude	Justice Honesty Gratitude
Patience/ Good Temper Magnificence Magnanimity Friendliness Brave Truthfulness	Patience Kindness Diligence	Fortitude	Patience Munificence Magnanimity Perseverance	Patience Asceticism Kindness Courage Truthfulness	Compassion Courage
Temperance Righteous Indignation Proper Ambition/ Pride Patience/ Good Temper Modesty	Temperance Humility Chastity	Temperance	Continence Humility Meekness Modesty/ Decorum	Courtesy Gratitude Unselfishness	Respect Humility Gratitude

The approach to relating the different virtues was accomplished by reading into the definitions as provided by the various authors and looking for relationships among meanings. For example, in relating different understandings of justice, the concept of justice as fundamentally being owed/due to a person would inform collecting other related concepts. Gratitude as a virtue necessarily involves the self and the other, and like justice is fundamentally relational in its application.

Identifying Core E/C Virtues

The purpose of this examination is to bridge what E/C profession(s) assert to be good (Codes of Ethics) to observable virtues/dispositions that can be connected to student formation. The collection of virtue terms presented in Table 1 serves as a draft vocabulary with which to examine E/C ethical codes tag canons/lines from the codes. Then by a counting/frequency measure, identify which virtues appear to be more essential (core) to the development of an E/C professional. Six codes were examined; to each statement from each of the six codes, a link to the top one or two implied virtue statements (Table 1) that appeared most connected/necessary for their implementation. Table 2 presents the mapping of the six NSPE Canons to the top two implied virtues from Table 1.

The approach taken makes several (hopefully reasonable) assumptions, beginning with the assertion that virtue enables the satisfaction of a particular ethical code; people need virtue to help us make hard choices in the real world [16]. Similarly, a second assumption is that ethics are well-founded standards of right and wrong that prescribe what humans ought to do [17]. Lastly, this approach assumes that the ethical codes proposed and maintained by various E/C professional bodies represent reasonable assertions as to the types of ethical considerations expected of E/C professionals.

Table 2. Mapping of NSPE Fundamental Canons to Virtues

NSPE Code of Ethics, Fundamental Canons	Implied Virtue
1. Hold paramount the safety, health, and welfare of the public.	Prudence + Loyalty
2. Perform services only in areas of their competence	Temperance/Humility + Prudence
3. Issue public statements only in an objective and truthful manner.	Truthfulness + Disinterestedness
4. Act for each employer or client as faithful agents or trustees.	Loyalty + Disinterestedness
5. Avoid deceptive acts.	Truthfulness + Prudence
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.	Justice + Temperance

Table 2 serves as a sample analysis: For the six canons in the *NSPE Code of Ethics*[26], a total of six different virtues were implied; ordered by frequency these were: Prudence (3), Loyalty (2),

Temperance (2), Disinterestedness (2), Truthfulness (2), Justice (1). An examination similar to that conducted for the NSPE codes was conducted for five other prominent E/C Codes of Ethics: AIChE[27], ASCE[28], ASME[29], BMES[30] and IEEE[31]. The prevalence of virtues connected to (and necessary for) canons in the code of ethics were counted and are summarized in Table 3. These virtue statements are presented in frequency order from most to least common in the six different engineer societies' codes of ethics.

Table 3. Virtues Implied in Examining Six C/E Codes of Ethics

Ethics Code (Statement Count)	**Implied Virtues (Ordered by count)**
NSPE (6) [26]	Prudence (3), Loyalty (2), Temperance (2), Disinterestedness (2), Truthfulness (2), Justice (1)
AIChE (11) [27]	Prudence (5), Truthfulness (4), Disinterestedness (4), Justice (3), Temperance (2), Humility (2), Loyalty (2)
ASCE (40) [28]	Truthfulness (15), Prudence (10), Disinterestedness (8), Justice (7), Humility (4), Respect (4), Fortitude (4), Loyalty (3), Munificence (2)
ASME (11) [29]	Prudence (6), Disinterestedness (3), Truthfulness (2), Loyalty (2), Humility (1), Temperance (1)
BMES (6) [30]	Justice (3), Prudence (2), Disinterestedness (1), Truthfulness (1)
IEEE (10) [31]	Justice (6), Prudence (4), Disinterestedness (3), Truthfulness (2), Loyalty (1), Humility (1), Temperance (1)

Using frequency as a simplified proxy for importance, examining the top two implied virtues for each code by frequency (including ties) yields four virtues that stand out as being most frequent in two or more of the six codes: Prudence (6x), Disinterestedness (4x), Truthfulness (3x), and Justice (2x). By no means does This analysis imply that these four virtues would be sufficient to satisfy the prescriptions of these six codes of ethics. These findings suggest rather that these four virtues are of principle importance and should be considered to be essential to any E/C program.

Prudence has often been defined as a cardinal virtue that orders all other virtues. Engelland calls this virtue "right reason in action" [17] where one "uses our practical reason to discern our true good in every circumstance and to choose the right means of achieving it." [32] One who is prudent "looks where he is going." (Proverbs 14:15) It entails understanding and careful, deliberate action with an end in mind.

Disinterestedness in any work or effort as originating in a sincere intention of service to the work itself, freeing man for genuine creativity to fulfill what the work itself demands. It is a virtue that entails not being dominated by one's own interests such as pay, career advancement, or any other interest apart from doing high quality work. [12]

Truthfulness includes "the love of the truth and the will that truth should be recognized and accepted," noting also that tact and kindness are necessary ingredients and that there are certain contexts where the whole truth should not be divulged. The practice of truthfulness as a virtue

entails making good on promises already made even in the face of confusion, temptation, adversity, or the vicissitudes of emotion and is essential to the development and maintenance of professional trust. [12]

Justice consists "in the constant and firm will to give their due to God and neighbor." (CCC 1807). In two of the six codes examined, this was strongly listed as the first virtue, while in others it was less frequently connected. For example, statements associated with Justice appear most often in the IEEE Code of Ethics, reminding its proponents of their obligation to treat all persons fairly, avoid injury to others, and protect those who report violations of the code from retaliation.

Discussion

The work presented here is a lens or way of thinking about the space in which ethics, virtue and competence intersect. The core finding is that six prominent E/C codes of ethics list canons or statements suggesting that the four virtues of prudence, disinterestedness, truthfulness and justice warrant significant inclusion in E/C education; that because of professional values, and particularly their integral part reflected in competencies, 'virtuous' engineering is essential to engineering education.

These four virtues warrant special consideration; certainly they appear essential due to their tight integration into the professional codes of ethics. But these four virtues bring an additional value to E/C education: individually and collectively they provide a window into dispositions integral to a virtuous engineer. Prudence is integral because engineering can not be successfully engaged without considering a project's multivariate outcomes. Disinterestedness requires the E/C practitioner to step away from their personal and at times even their corporate biases to work for the best solution for all, especially the client and/or the public. Without truthfulness, violations of trust between individual practitioners, firms, and society would critically debilitate functioning contractual relationships, causing great mistrust and disorder. Central to justice is the person [12], defining the target or goal and informing all E/C objectives. The role of the person is reflected in the practitioner's enacted judgement: the inquiry and choices reflecting the goodness of engineering as it is conducted, the goodness of the E/C product, and consequently the goodness of the practitioner.

While of value, this finding does not suggest that other virtues are somehow unimportant or are only of secondarily/tertiary importance. Similarly, any program focused on prudence, disinterestedness, truthfulness and justice should include an expansion to include presenting and connecting students to the dispositional aspects of these virtues [1], [9] and subsequently connection to the competencies they develop in their program. While these provide a 'minimal' set of virtues to consider developing as an ethical professional, this by no means identifies the core dispositions needed to become a successful professional (see lists provided in [3], [4]). Nor does this exploration consider other candidate virtues/dispositions recommended for E/C professionals, such as empathy [33].

At the time of writing (2021), the only E/C program known to the authors with a published programmatic focus on virtue is housed at Wake Forest University [21]. For these findings to be of value, it is necessary that virtue, and the integration of particular virtues into E/C programs be considered.

Integration of Virtue into Curricula

Engelland describes how they integrate virtue and integrity into a business curriculum [17]. He and his colleagues identified a particular virtue to be emphasized within a course, and collections of desired virtues are emphasized among the required courses in the program. Within each identified course, the goal is to showcase virtue in action as related to the course subject, e.g., through case studies, class exercises and videos to showcase and convey virtue. This can be assessed through pointed discussion questions and assess how the virtues play a role in particular assignments. Similar questions can be used to assess students' experience in internship experiences and the students' responses may be used to identify the most promising companies for virtue development. [17] For E/C programs, these integration methods could all be employed, but the particular virtues emphasized in a business program would likely be different.
To support sustainability, engineering faculty can regularly compare their own approaches in discussion of the virtuous practice of engineering and computing in their respective courses, encouraging their colleagues to do the same and stimulating new ideas to integrate this practice across the curriculum. Faculty members can review the most discussed virtues and look for gaps between program-wide goals and actual implementation at the course level.

Assessing virtue is necessarily difficult, but not impossible. Assessing the knowledge, skill and disposition involved in competency suggests assessing disposition as reflected in the conduct of the work. At the simplest level, this can be knowledge of the applicable disposition or how it should be applied but should extend into reflective work inviting the student to see their own work/behavior through the lens of the particular disposition being valued in the course. One approach is the use of action-value assessment involving having students self-assess on how a virtue/disposition should be reflected in their work (3rd person), how they observed that virtue/disposition was practiced by their team (2nd person), and how they integrated the particular virtue/disposition into their teams' work (1st person) [34].

Some examples of reinforcing the virtue of disinterestedness may be illustrative: Faculty members might praise teams that go above and beyond the basic expectations in a project with "a sincere intention of service to the work itself." They may specifically cite this virtue and its definition in a project grading rubric, allowing extra consideration and reinforcing this virtue in engineering practice. Also, students may complete self-assessments during and after project work. Probing questions may be asked such as "How is my view of and contribution to this project impacted by my self-interest (individual grade, particular career interests, likes, dislikes, etc.)?" Additionally, in reflecting on the ethical dimensions of historical engineering successes or failures, students may be asked to cite ways in which this particular virtue - among others - was or was not practiced.

Future Work

While the goal of this exploration is the identification of which virtues appear core to E/C professions, this still leaves open the question of how to leverage virtue-based education to support the formation of ethical E/C professionals. While models for these efforts abound, numbers of character-based approaches to education [15], [17], [21], [25] suggest (in different forms) that effective student formation aims to help students know (1) how to be ethical; (2) when to be ethical; and (3) why to be ethical, and it does so by asserting goals in virtue development, integrating virtue education across the program, training in good habits, and modeling virtue within a program. Given these findings, further exploration into character-based virtue ethics education is not just warranted, it is necessary. Similarly, this particular study has focused on a virtue vocabulary rooted in a Christian/western philosophy; how other cultures and philosophical traditions might view this differently is another area for exploration.

This work highlights the parallel aspects of competency and virtue--that they are both observed and contextually located and require intentional formation. For E/C students and practitioners alike, robust development of either competency or virtue necessitates continual engagement, frequent reflection, and continuous improvement. This also implies that individuals acting alone could not effect this improvement, but that whole teams and programs must coordinate to improve both competency and virtue development. Similarly, this work suggests that in order to promote an ethical practice of E/C, naming and intentionally promoting certain virtues, a set of shared values and a common vision of the Good, is essential.

This work also suggests a future exploration of the relationships that connect core virtues to their dispositional components and to competency development. Similarly, we suggest program development work exploring the integration of these (and related) virtues into E/C programs and development of best practices for assessing effectiveness. Lastly, identifying these core virtues highlights the need to raise the level of analysis in which our students engage, to address the goals of engineering and the capacity of engineers to practice engineering in a way that promotes human flourishing [35].

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