Qualitative Study of Professional Virtue Development in Engineering

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***Abstract*— This research-to-practice work-in-progress paper describes the approach and methods for a qualitative study of early engineering students' development of professional values. The goal of the research program as a whole is to study students' understanding of professional virtues and how various virtue formation activities affect how students establish positive ethical traits. This specific study was designed to understand the foundation upon which these values can develop and become integrated with the practice of engineering.**

This study focuses on individual interviews with engineering and computer science students, primarily freshmen and sophomores, at Franciscan University in Steubenville during the spring 2022 semester. Students were asked to describe their motivation to study engineering and their perception of virtues for professional engineering and computing practice. Responses to broad questions were further probed to gather relevant details. This paper describes the background, motivation, and methods for the initial study in this research program.

Keywords — Virtue Ethics; Competency Development; Motivation, Engineering Ethics;

I. INTRODUCTION

Beyond technical knowledge, diverse skills and dispositions have been identified as part of engineering education, including critical thinking, empathy, service and teamwork. Because these capacities are necessarily ordered to morally good ends, have a motivational component that skills often lack, and involve evaluating and addressing potential conflicts among values, Koehler *et al* identify the benefits of recasting these types of capacities as virtues [1]. Other researchers have suggested that bridging engineering ethics into behavior necessarily involves virtue orientation [2][3]. Researchers exploring competency development in engineering and computing (E/C) students suggest that the dispositional aspects of competency imply that developing professionally and technically competent students also includes helping them develop professional values[4] and virtue [5]. These findings suggest that professional virtue is also an area of E/C professional identity worthy of further study.

II. BACKGROUND

Peters [6] notes that the activities and content of early E/C education strongly influence what students find important to learn. Because both employers and professional organizations are increasingly highlighting the need for professional values in addition to technical knowledge in successful engineers, engineering educators must ensure that students are developing these values beginning in their first year of undergraduate studies. Franciscan University's engineering faculty also want to ground these professional values on virtues to establish positive ethical traits as a foundation upon which these values can develop and become integrated with the practice of engineering.

Current research (e.g., [7][8]) is still investigating how to quantitatively measure different aspects of virtue so that changes can be empirically investigated, but qualitative assessments still provide information to guide education research [6]. The goal of the current study is to gather early engineering students' perceptions of virtue in the context of their goals and identity as engineers. Establishing this baseline will provide additional data for proposing quantitative measurement approaches and for evaluating the effectiveness of educational initiatives to develop virtue among Franciscan University engineering students in their curriculum. Engineering faculty will be following these students to assess the success of their curriculum in a longitudinal study established through the current research.

A. Disciplinary Knowledge

Knowledge is described as the "know-what" behind the skills "know-how" and dispositions "know why" of technical education [9] transmitted in the undergraduate E/C education. E/C students normatively develop professional and technical knowledge through the concepts and methods experienced in their undergraduate programs [4]. As this knowledge includes dispositional terms that describe virtue, the terms used by students and their classification are important to the study.

Example terms distinguishing 'technical' and 'professional' concepts are presented in Table 1. Technical terms stem from the concepts, facts, and propositions which students learn as they complete class assignments and projects [8]. In contrast, professional terms refer to knowing how to implement this knowledge to solve problems, especially those with and for other people. Communication clarity, creative thinking, and time management skills are examples of this professional knowledge [9]. These knowledge types may be developed

independently of each other, but experience using both appropriately is highly desired by employers [9][10]. Understanding students' initial descriptions of each component can frame the curriculum for current and prospective students.

Table 1. Custom Categories for Knowledge

Category	Terms for this category
Professional	collaboration, critical thinking, ethical perspectives, leadership, multi-task prioritization, problem-solving, project management, quality assurance, teamwork, time management
Technical	animation, apps, data structures, design, electronics, equipment diagnosis, graphics, internet, inventory management, programming, robotics, scripts, signal processing, visualization

B. Motivation

Motivation is an integral part of how students come to acquire knowledge and develop skills in engineering [8]. For students in general, the type of motivation present during learning determines the amount and duration of effort expended as well as which knowledge is acquired. Prior research indicates two types of motivation that contain internal and external characteristics [11]. Intrinsic motivation supports engagement in behavior that is inherently satisfying or enjoyable without a specific outcome required. This type of motivation produces various benefits such as persistence and psychological well-being [11]. Examples of intrinsic motivational factors include learning for the sake of the knowledge gained, utilizing natural gifts in particular subjects, and serving the community by applying knowledge to solve problems. In contrast, external motivation supports performance of behaviors that are conditional upon the desired outcome but independent of the action itself [11]. Money, reputation, and family pressures are examples of external factors that influence effort and behavior choices. A critical characteristic of these extrinsic motivators is that they elicit and maintain behavior in areas that are not intrinsically engaging. Table 2 provides a more extensive list of examples of intrinsic and extrinsic motivation common among engineering students.

Table 2. Custom Categories for Motivation

Category	Terms for this category
Extrinsic	money, reputation, prestige, family pressure, parents, competition, fear of punishment, fear of failure, pleasure, status, ranking, gold stars, advancement
Intrinsic	creativity, learning, challenge, gifts, teach, help, serve, mastery, curiosity, belonging, freedom, purpose

Which motivation is most salient among students can guide the design of effective educational programs. When both intrinsic and extrinsic motivation are present, research has demonstrated that external rewards shift an individual's intrinsic reasoning for engaging in the activity to focus on these rewards [11]. Thus, educators should be aware of student motivations and resist focusing on rewards to elicit the substantial effort required to learn engineering. Instead, seeking to increase student understanding of intrinsic rewards may encourage sustained effort, broader attention, and perseverance in the face of difficult learning material. Cultivating virtue among engineering students could thus enhance the salience of intrinsic motivators.

C. Virtue Ethics

Virtue ethics as a philosophical system aims at asking two questions. What is a good human person? What virtues should be developed in becoming a good, moral human person? Virtue ethics focuses on definitions of virtues and vices, the education or discipline necessary to become virtuous, and the end to be achieved [12]. In a virtue-ethics framework, virtue is defined as a well-motivated disposition to act in self- and other-benefitting ways on the basis of knowledge about those actions [7][13]. This emphasis on virtue reflects character development, especially in the connection between the actor's choice and their intention for the good by their chosen actions.

From an educational perspective, this emphasis on character development emphasizes a learner-centered perspective in which character is developed through role-modeling and emotional contagion. In addition, activities and discussions afford opportunities to witness and/or enact a particular virtue and thus equip students with language and tools that support character development. Progress, particularly with regard to virtues and the dispositions that affect them, can be measured through self-reports but also more objective methods [5][7][8].

Although virtue ethics establishes a philosophical underpinning for virtue education, little research has been focused on discipline-specific virtue formation (e.g., [1][2]). The approach underpinning the current study stems from a dispositional view of professional virtue, suggesting that dispositions are components of virtues for which disciplines can identify dispositions that better frame their professional values (see [5]).

D. Research questions

Educational approaches that strive to promote virtue development center on the assessment of student values. As values are fundamentally affective in nature, examining the foundation for promoting the development of virtue among engineering students requires an understanding of the students' disciplinary knowledge, motivation, and virtues. In studying students' conceptions, these three areas should be explored independently and in the context of students' current associations among them. Specifically, we propose four research questions for this study.

R1 What knowledge do students describe that they hope to develop during their undergraduate career?

R2 What motivates these students to pursue an engineering degree?

R3 What virtues do students say are necessary to being a virtuous engineer?

R4 Is there an association between the focus of student knowledge goals, their motivation for pursuing the degree, and the types of virtues described within an interview?

These research questions were motivated by the implementation of preliminary interventions to help students begin embracing E/C virtues such as those described in [5]. Primarily, this study was qualitative as an initial work to help understand student perspectives on professional virtue.

III. Methods for Data Collection

This study included a total of 19 participants between the ages of 18 and 22. Participants were recruited from required first and second year E/C courses. Participation was encouraged but voluntary. A script was provided to instructors explaining the purpose of the study and requirements for participation. A total of 72 students were invited from three courses, for a participation rate of 26%.

As shown in Figure 1, 8 participants (42.11%) were engineering majors, 8 (42.11%) computer science, 2 (10.53%) another STEM field, and 1 (5.26%) undeclared. Six participants were female and 13 were male. A total of 5 freshmen, 8 sophomores, 5 juniors, and 1 senior were interviewed.

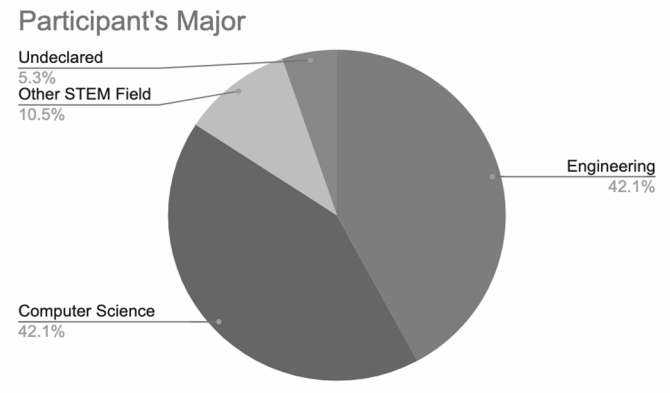

Figure 1. Distribution of participants by major

After students signed up for an interview date and time on a Google Sheet, they received an email requesting that they complete an online demographics survey before the interview. At the scheduled interview, participants signed a consent form before the interview commenced. Each participant was individually interviewed by one of the student researchers using a list of six questions. These six questions asked about prior experiences leading to the E/C major, expectations of work in the field, postgraduate goals, what it means to be a virtuous worker, and key motivators of the individual. As appropriate to the participant's major, questions that included a discipline adjective would be tailored to include the appropriate professional adjective such as "engineering" or "computing" or "STEM." Follow-up questions were asked as needed to ensure that students provided sufficient detail for relevant context and understanding of responses that would be analyzed from text transcriptions.

The interviews lasted between fifteen and thirty minutes and were audio recorded. Each recording was then automatically transcribed using Otter.ai software. These transcriptions were additionally reviewed for errors by an interviewer before data analysis. Figure 2 shows an image of the first page of one interview.

MN72EN

Thu, 3/10 6:50PM • 23:14

SUMMARY KEYWORDS

computer science, class, franciscan, people, job, virtues, develop, engineers, feel, skills, professional, idea, teach, code, good, desire, professors, big, brother, goals

Dominique Tedrow
00:00
Both employers and professional organizations desire to have engineers be more well-rounded individuals. This means that you're not only technically competent (hard skills) but also have solid professional values in your field of study (the softer skills that are interpersonal). Our faculty at Franciscan University desires to develop these values in each student throughout all four years at Franciscan University. We also want to foster these professional values as virtues for you to use as a professional and well-rounded engineer, scientist, or computing professional. The goal of the study is to gather early students' perceptions of virtue in the context of their goals and identity as engineers, scientists, or computing professionals. This will act as a baseline which will provide additional data for quantitative measurement approaches in the future as well as evaluating growth and development and virtue through our curriculum here at Franciscan. All this will be used to shape and form the growing engineering program here. To start off, what classes, activities, experiences or persons contributed to your desire to pursue a degree in computer science?

MN72EN
01:23
Well, it all started back when I was 13 years old. I come from a large family. I'm a homeschooler. One of my older brothers, Steven, went here. He took a few computer science classes and brought that home to me. I needed a new hobby, and so he's like, "Hey, this looks cool." I played a lot of video games when I was a kid and so I had a really strong desire to learn this code to create make my own video games. I started off really simple. I didn't have any direction in my high school, so I basically read a textbook and I taught myself how to code. And, coming here I've definitely been shaped a lot. I'd say my love of computer science has moved a little bit more broadly out of just programming into the physical, more hardware side of things. I'm not sure if this is relevant to the question but, getting my job at the IT help desk has really helped me to work with computers physically, and not just software things. My range of interest within the field has definitely broadened. A class I took that really changed what I want to do with computers would be my psych class, perception. Basically, through that class, I learned that a lot of people have difficulty perceiving how to use computer systems. It spawned this new idea of combining psychology and computer science to create computer systems that old people can use, people with ADHD can use, all sorts of things (if that's a possibility).

1

Transcribed by https://otter.ai

Figure 2. Sample Transcript Fragment

IV. Methods for Data Analysis

Transcriptions will be evaluated using the Link Inquiry Word Count (LIWC) software which evaluates text and calculates a proportion of words that fit categories specified in the LIWC dictionary[14]. The pre-programmed LIWC dictionary includes over 80 categories of words such as affect and psychological processes. To address the specific research questions, additional terms will be programmed in the custom dictionary for additional analysis in LIWC. Tables 1, 2 and 3 detail the initial mapping between the custom categories and text in the transcripts. Each of the categories will be pre-populated with terms from the literature as a baseline. We anticipate several rounds of review and refinement of the terms, followed by statistical analysis to identify patterns and differences by major, dominant motivation and knowledge goal.

The initial terms mapped into different types of knowledge were identified from a combination of sources. First, the CC2020 Paradigms for Global Computing Education [10] specifications for computing knowledge and knowledge elements were reviewed for key terms based on detailed discussion by engineering educators and computing professionals. Second, the Glassdoor website was examined for the leading engineering skills sought by employers. Finally, several transcripts were read to identify typical words used by

students during the interviews. Table 1 depicts examples of terms from these sources.

The initial terms mapping into the two types of motivation were identified from the Encyclopedia of Personality and Individual Differences [11], which provides differentiating characteristics. In general, characteristics for intrinsic motivation included interest, enjoyment, and inherent satisfaction to do a specific task. On the other hand, extrinsic characteristics encompassed behavior that required instrumental and outside motivation [11]. Second, an empirically derived classification mapped the regulatory style of learning (extrinsic and intrinsic motivation) with the associated processes [15]. Associated processes describe the type of behavior classified under the different aspects of each motivation type. This aided the qualitative analysis of identifying which words or phrases, used in the interview process, corresponded with intrinsic or extrinsic motivation. Finally, several transcripts were reviewed to identify typical words used by students in the interviews regarding motivation. Table 2 depicts examples of terms from these sources.

The approach to categorize virtues stems from Aquinas' work on the cardinal virtues. This is rooted in the observation that all virtues are dispositions, but not all dispositions are virtues [13]. Specific dispositional terms have been proposed as related to E/C competency. These initial terms were drawn from a competency-based analysis of computing job descriptions, and categorized as competencies or competency components: knowledge, skill or affect [9][10]. This analysis was extended by examining various engineering codes of ethics [3] and more recently by identifying dispositions in support of lifetime learning [5] and through a method for mapping dispositions to the four cardinal virtues. As with the other categorizations, terms encountered that are similar in meaning to the baseline virtue vocabulary are grouped. Table 3 presents the preliminary state of the virtue categories.

Table 3. Custom Categories for Virtue

Category	Terms for this category
Fortitude	resilient, self-directed, truthful, proactive, passionate
Justice	interdependent, collaborative, responsive, disinterested
Prudence	reflexive, creative, inventive, inquisitive, connective, responsible, meticulous, deferential
Temperance	endeavoring, purpose, driven, focus, adaptable, persevering, disciplined, grit

Selection of the final categories and terminology to be mapped to these categories will be identified through an iterative process of running the text analysis, reviewing the results, and assessing the fit of these results against the research questions and the content of the interviews.

V. SAMPLE RESULTS

To describe the current state of knowledge, motivation, and virtue perception among early engineering students (questions R1-R3), counts of the numbers of statements in each category per student will be calculated. Basic descriptive statistics of these values for the group will be presented, along with sample statements in each category to illustrate student phrasing and understanding. To explore linkages between these categories among students (R4), correlations between each set of categories (e.g., knowledge x motivation, motivation x virtue) will be measured to identify patterns of overlap, trends and clusters of characteristics that describe sub-groups of students. Figure 3 provides an illustrative illustration of the analysis envisioned to more fully understand student perceptions.

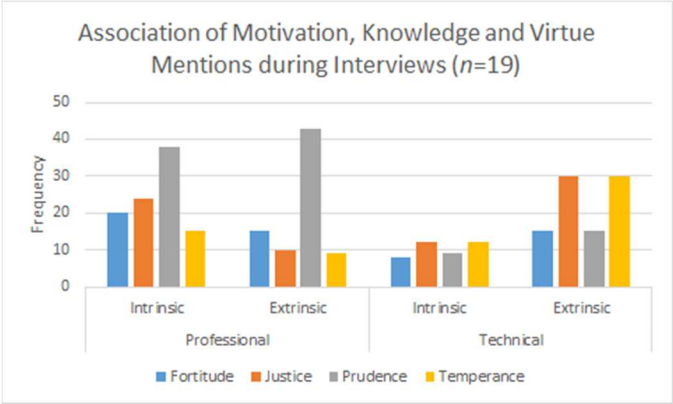

Figure 3. Illustrative Chart of Results

VI. CONCLUSIONS AND NEXT STEPS

The next steps are to finalize the custom dictionaries, count terms in the current interview sets, and begin analyzing the results. We especially want to identify relevant virtue formation activities to begin in the fall semester, both for new freshmen and for rising sophomores and juniors. With a longitudinal study of the effect of curriculum changes on student perceptions and in building E/C competencies planned, we anticipate repeating these interviews for new students and evaluating the impact of the virtue formation activities on students interviewed for the current study. Thus, we hope to establish validity of the current approach in describing relevant perceptions of virtue by next summer.

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