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Paper: A Review of Personality Type Theory in STEM Education and Implications for First-Year Engineering Teaching Assistants

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A Review of Personality Type Theory in STEM Education and Its Prevalence and Implications for First-Year Engineering Teaching Assistants

Introduction

Teaching Assistants (TAs) are commonly used in undergraduate STEM courses, especially for laboratory-based courses and large enrollments courses. Laboratory-based courses typically employ TAs to run the lab environment and to assist students in running their experiments with equipment in the lab. Large enrollment courses typically employ TAs to make the course more manageable for the instructor. Depending on the institution and the course, TAs may be either undergraduate students or graduate students.

TAs have many different kinds of responsibilities depending on the institution, the subject matter, the instructor, and the course structure. However, some common TA responsibilities include lecturing, leading discussions, leading review sessions, conducting labs, grading student assignments, motivating students, helping students feel comfortable, providing feedback to students, assessing student prior and current knowledge and understanding, applying formative assessments, and completing training programs [1]. Much literature exists to support the use of TAs in STEM undergraduate courses as having a positive impact on student content knowledge, quality of education, and student retention.

Of specific interest to this paper are First-Year Engineering (FYE) courses [2]. Although many institutions specifically call these FYE courses or programs, other equivalent names exist such as Freshman Engineering or General Engineering. One approach to FYE is to have students take a set of courses on engineering fundamentals which are needed in any engineering major, to begin to develop the skills needed later in their engineering majors. Many FYE programs have large enrollment, since all incoming engineers go through these courses, and thus, many FYE programs employ TAs. TAs in FYE often help to manage the instruction and grading for students, but they also help the students in their developmental transitions from high school into engineering.

Although the above goals for FYE courses and TAs are often stated in literature, one gap in the literature identified from an initial analysis of titles and abstracts of research articles about UTAs/GTAs and FYE is that an initial literature search shows there appears to be no literature regarding the affective effects of TA personality on students in FYE programs, despite literature existing on this topic in other STEM fields. This is surprising because one of the main purposes of having TAs in a FYE program is to help students in their transition into college by being mentors, being examples, and being supportive resources for students . The authors of this paper postulate that the personality of a TA may influence the interactions between that TA and a student and thus the effectiveness of the instruction received by the student. In order to establish a foundation for future TA personality studies, the authors sought to answer these two research questions:

Research Question 1) What is the prevalence of personality type terms in STEM education Teaching Assistant literature?

Research Question 2) How does the prevalence of personality type terms in FYE literature map to the overall STEM education Teaching Assistant literature?

Research Question 1 is addressed through analysis of a selected number of STEM education personality typing studies to present an array of research designs which could be adapted. Research Question 2 is addressed through the text mining for personality type terms in a large set of STEM education TA literature articles acquired from a systematic literature review.

The Background section below presents information about personality type theory and an analysis of selected STEM education personality articles. The Methods section describes the systematic literature review methodology and text mining methods used to collect and analyze the articles. The Results section presents the personality adjective counts found in each set of articles, and the Discussion section describes how the two sets of articles compare and gives possible interpretations of this comparison. Lastly, the Limitations and Future Work section presents acknowledges some simplifications made in this study and provides opportunity for future study on the prevalence and influence of TA personality factors on students in FYE and STEM.

Background

Personality Typing

Personality typing is a theory from psychology which suggests that a person's personality can be described by ascribing it one of a number of possible types based on quantitative measurements of behaviors associated with each type. Several personality type measurement instruments exist, and each instrument is based on a different set of personality domains and resulting personality types. Three of the most common personality type instruments used in educational research settings are the Myers-Briggs Type Indicator (MBTI), the True Colors test instruments, and the Five-Factor Model (FFM).

The Myers-Briggs Type Indicator (MBTI) measures a person's preferences on four dimensions which are derived from Jung's Theory of Psychological Types [3]. A dichotomy is defined for each dimension, and the type instrument results in the person's preference of the two ends based on the person's responses to the behavior-related items in the test. Since there are two possible preferences for each of the four dimensions, there are 16 different personality types represented by the MBTI. The dichotomous dimensions and corresponding paired preferences for the dimensions are:

- Orientation: Introversion (I) and Extraversion (E)
- Cognitive Perceiving Function: Sensing (S) and Intuition (N)
- Cognitive Judging Function: Thinking (T) and Feeling (F)
- Attitude of the Functions: Judging (J) and Perceiving (P)

The True Colors taxonomy is a simplification of the MBTI created by Lowry based on Keirsey's four temperament groupings [4]. Many versions of a test instrument utilizing the True Colors taxonomy exist. One of the most commonly used versions is the True Colors "word cluster"

version. This instrument is used because it is relatively quick to administer and is easily accessible. The True Colors "word cluster" test has four personality dimensions identified as colors:

- Gold
- Orange
- Blue
- Green

The Five-Factor Model (FFM) is also called the Big Five personality traits or the OCEAN model [5]. It was created based on the lexical hypothesis in psychology, which when applied to personality states that of all the possible personality traits which could be identified by humans, the most important ones develop naturally over time to become part of our shared language. Based on this hypothesis, the creators of the FFM used a dictionary to determine thousands of personality-related terms and then grouped them and parsed them down to just the five most important and most encompassing personality traits which represent all the others. Thus, the personality traits in the FFM are based on empirical word data and not on a pre-existing psychological theory. The five factors are:

- Openness
- Conscientiousness
- Extraversion
- Agreeableness
- Neuroticism

Openness refers to introspection, intellectual curiosity, willingness to entertain novel ideas, and imagination. Conscientiousness refers to being purposeful, being strong-willed, determination, accomplishment, self-efficacy, and reliability. Extraversion refers to being social, a preference for large groups, being talkative, being active, and assertion. Agreeableness refers to being altruistic, being empathetic towards others, a willingness to assist others, and an assumption that others will be helpful in turn. Neuroticism refers to a tendency to experience negative affects such as embarrassment, guilt, and anxiety. Each of the five traits in the FFM is represented as a scaled dimension such that a person could have any level of score in each dimension ranging from low to high. The resulting personality type from the FFM is represented as a series of scored levels in each of the five personality trait dimensions. For example, a person may have a high level in openness, conscientiousness, and agreeableness but have a low level in extraversion and neuroticism.

Although the MBTI may be the most commonly used personality type instrument of the three, with documented uses spanning from educational settings to industrial settings, there are concerns about the instrument's validity [6]. Since the True Colors test instrument is derived from the MBTI, there may be similar issues with validity. However, the theory behind the MBTI and True Colors assessments is generally regarded as strong. The FFM has undergone more rigorous validity testing [7], but there are criticisms that it is based primarily on empirical evidence rather than pre-existing theory. For this study, the FFM is chosen because of its rigorous validity and the accessibility of corresponding measurement instruments.

Selected STEM Education Personality Typing Studies

Although the relationships among TA personality factors and student outcomes are not fully understood for STEM courses, some prior educational studies have Shown that personality typing is one tool for identifying relationships among personality factors and course factors. Most STEM educational studies involving personality investigate the personality of the students in the course and how different elements of their personality types correlate to other outcomes such as course grades, retention, self-efficacy, or affective outcomes. For example, Felder conducted a foundational study in 2002 based on a previous longitudinal study which laid out a lot of initial findings for personality on first-year engineering students at large universities [8]. This study used the MBTI and showed that personality preferences correlate to student performance in first-year engineering students. Felder referred to the preferences in the personality trait dimensions as preferences of learning styles. The results of the previous personality studies showed that first-year engineering students with personality preferences of Introversion, Intuition, Thinking, and Judging generally outperformed other students with personality preferences of Extraversion, Sensing, Feeling, and Perceiving along each dimension. The hypotheses of Felder's study were that active and cooperative learning should help extraverts and feelers to succeed more and that inductive instruction should have sensors. While only the extraverts showed significant improvement as a result of the study, this sets up the possibility of different modes of instruction helping students of different personality types to perform better in engineering.

In addition to evidence that instructional mode impacts students based on their personality type, students' own personality developments may also impact their success students in a personality-dependent manner. This notion is supported by a study conducted by Hall, et al., in 2015 using the FFM to correlate personality traits to retention of students in first-year engineering [9]. Of the five dimensions in the model, only Conscientiousness resulted in being a statistically significant predictor for student retention. This difference is particularly powerful for predicting whether a FYE student will persist into engineering or leave engineering in poor standing. The study suggests that perhaps students who leave in poor standing had more difficulty planning and organizing, conducting higher-order thinking, practicing self-discipline, and generating motivation to achieve. All of these elements are associated with high levels of Conscientiousness. Many of these Conscientiousness elements may be related to expected developments in FYE students, such as in developing good study strategies, learning how to manage time, and becoming excited about engineering. As such, not only the mode of instruction but also students' own personality developments may be influential in student success.

Interactions between instructors and students in the classroom setting, and the effect of those interactions on student outcomes, depend on the personality of both the instructor and the student. For example, a 2017 study by Harlow, et al., investigated the personality types of faculty for an introductory physics course in comparison to the personality types of physics major students and non-physics major students taking the introductory physics course [10]. This study used the True Colors "word cluster" assessment to determine the personality types of thousands of students. The authors correlated non-physics major students' personality types with many other variables, including course performance. However, the comparison of the faculty with the students showed the majority of faculty tended to have mostly Green personality types whereas

the majority of non-physics major students tended to have mostly Gold personality types but all four colors were heavily represented by the students. Thus, this difference in personality representation at the faculty level may have some influence on the success of the non-physics major students. Although that study sets up the possibility that instructional personalities of faculty affect student outcomes, it is still not known how the personalities of *TAs* in an instructional role influence student outcomes.

There appear to be no studies directly investigating the personality of TAs in any STEM courses in relation to student outcomes. However, it is postulated that by looking at studies done with student personalities in mind and at studies done with instructor personalities in mind, along with studies of FYE students and other STEM instructors, the landscape around the gap of TA personalities can begin to be defined.

Methods

To answer the research questions, a systematic literature review (SLR) was conducted. An SLR is a methodological process for identifying, collecting, and analyzing a large collection of literature articles in a systematic way. Borrego, Foster, and Froyd (2014) identified eight steps to writing an SLR [11]:

1) Decide to do a systematic review
2) Identify scope and research questions
3) Define inclusion criteria
4) Find and catalogue sources
5) Critique and appraise
6) Synthesize
7) Identify limitations and validity concerns
8) Write the review

Three databases were accessed: Academic Search Complete, Education Resources Information Center (ERIC), and Scopus. A search string using Boolean logic operators was developed to gather all articles relating to TAs in STEM education courses from the three databases. The final search string was:

("teaching assistant*" OR "teaching associate*" OR “UTA*” OR “GTA*” OR “learning assistant*” OR “peer leader*”) AND ("STEM" OR "engineering" OR "science" OR "math") AND (“undergraduate*” OR “graduate*”)

Inputting this search string into all three databases resulted in 2,639 initial articles. From this, MATLAB and Excel codes were used to condense the list of articles and remove ones which were duplicated across the databases or which did not have sufficient search string matching within the title or abstract. Next, more specific inclusion and exclusion criteria were then developed, and a team of researchers assisted in reviewing each article title and abstract to further refine the list. Last, particular tag identifiers corresponding to TA type, course subject type, and engineering program type were chosen. The team of researchers assigned each article appropriate descriptive tags to label the contents within STEM education TA literature. These

tags included the discipline of the course under study, the types of TAs utilized, and whether or not the article specifically described a first-year engineering course. Throughout this SLR process, quality checks were performed to ensure inter-rater reliability and effectiveness of inclusion and exclusion criteria. The end result of the SLR process was a master list of 710 articles which met all the inclusion criteria, did not meet the exclusion criteria, and were tagged according to article type. From the resulting 710 articles, 42 of them were tagged as being FYE TA articles.

To assess the prevalence of personality type terms in the acquired TA literature, the FFM of personality typing was chosen as a lens. Because the FFM is based on an empirical word factor analysis, there exist lists of personality adjectives associated with each of the five personality factors. Thus, the extent to which an article references personality attributes can be measured as the extent to which these personality adjectives appear within the text of the article. The list of adjectives loading onto the five factors from Ashton, Lee, and Goldberg (2004) was chosen for this analysis. Their terms for the five factors are: agreeableness, conscientiousness, extraversion, emotionality, and openness to experience. In this case, emotionality is negatively correlated to the factor neuroticism. Emotionality and neuroticism exist on the same factor scale. The terms which load positively onto emotionality will load negatively onto neuroticism, and vice versa. In their paper, the authors list 167 personality adjectives which each highly loaded onto one of the five factors based on a combined American-Australia sample study.

Text mining was implemented with custom MATLAB code to determine the prevalence of these 167 personality-descriptive adjectives within the TA literature from the SLR. The text mining code process involves opening each article as a PDF file, extracting the entire text of the article as a string, iterating through each personality adjective to determine if it is found within the extracted text or not, keeping track of the number of counts for each adjective in each article, and then summing all of the counts for each adjective across all of the articles in the set. Thus, the prevalence of personality-descriptive adjectives is reported as the number of counts of each adjective from the chosen FFM loading list.

Results

The text mining process for determining counts of personality-descriptive adjectives was conducted twice. First, it was conducted for the entire set of 710 STEM education TA literature articles. At the time of writing this draft, only 612 articles have been acquired for analysis.. These 612 articles are presented as the entire set of STEM education TA literature articles for now until the remaining articles are prepared. Second, it was conducted for the specific set of 42 FYE TA literature articles. One of the 42 FYE articles could not be analyzed by the MATLAB code due to it being encrypted, so, the number of FYE articles analyzed in this paper draft is 41.All 41 of the FYE articles are contained within the full 612 article set, as well. Thus, the 41 FYE articles are a subset of the full 612 article set.

The subplot Figures 1 and 2 present the results of the text mining with the counts for personality-descriptive adjectives which had nonzero total counts in the full set. The counts are organized into five plots corresponding to the five factors and the adjectives loading to them.

The Openness plot in Figure 1 shows that the term *traditional* may be overly represented as a personality-related adjective. It has by far the greatest number of counts. In addition, *traditional* may refer to things other than personality; it may refer to methods of instruction, for example. For this reason, it is expected that the actual number of instances in which the term *traditional* is used in a personality sense is probably much less than the number of total counts shown in Figure 1. As such, further analyses were conducted with and without *traditional*.

Tables 1 and 2 present the total number of adjectives found with nonzero counts and the corresponding total number of counts of those adjectives. These numbers are organized by personality factor, and versions with and without the *traditional* adjective are given.

Out of the full 612 articles, 570 of them had at least one count of a personality-descriptive adjective, and out of the 41 analyzed FYE articles, 37 of them had a least one, as well.

Comparing the sets of articles in terms of percentages of counts associated with each factor from Tables 1 and 2 shows similar make-ups. The similarities are highest when the *traditional* adjective is removed. The biggest difference in percentage between the two sets is found in comparing the Conscientiousness percentages.

Table 1: Personality adjective counts results for all STEM education TA articles.

Personality Factor	All STEM Articles (612)				
	Number of Loading Adjectives with Nonzero Counts	Factor Counts	Factor Counts without Outliers	Factor Counts Percentage of Total	Factor Counts without Outliers Percentage of Total
Openness	9	2340	662	34.08%	12.76%
Conscientiousness	15	3186	3186	46.40%	61.41%
Extraversion	14	266	266	3.87%	5.13%
Agreeableness	10	607	607	8.84%	11.70%
Emotionality (vs. Neuroticism)	11	467	467	6.80%	9.00%
TOTAL	59	6866	5188	100.00%	100.00%

Table 2: Personality adjective counts results for FYE TA articles.

Personality Factor	FYE Articles (041)				
	Number of Loading Adjectives with Nonzero Counts	Factor Counts	Factor Counts without Outliers	Factor Counts Percentage of Total	Factor Counts without Outliers Percentage of Total
Openness	5	57	29	24.46%	14.15%
Conscientiousness	11	151	151	64.81%	73.66%
Extraversion	3	6	6	2.58%	2.93%
Agreeableness	3	8	8	3.43%	3.90%
Emotionality (vs. Neuroticism)	4	11	11	4.72%	5.37%
TOTAL	26	233	205	100.00%	100.00%

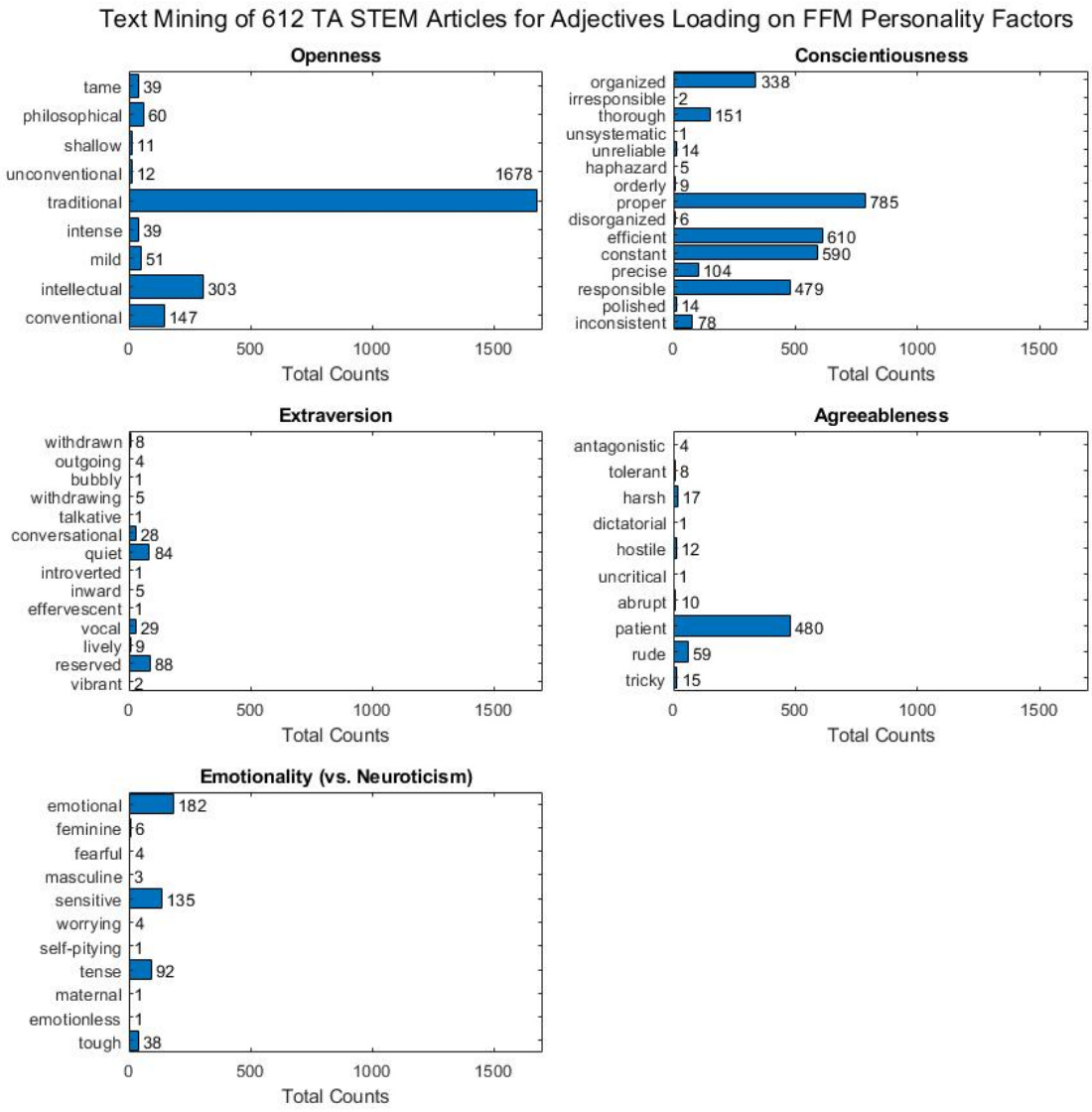

Figure 1: Subplot results for text mining of 612 STEM education TA articles for FFM personality-descriptive adjective counts.

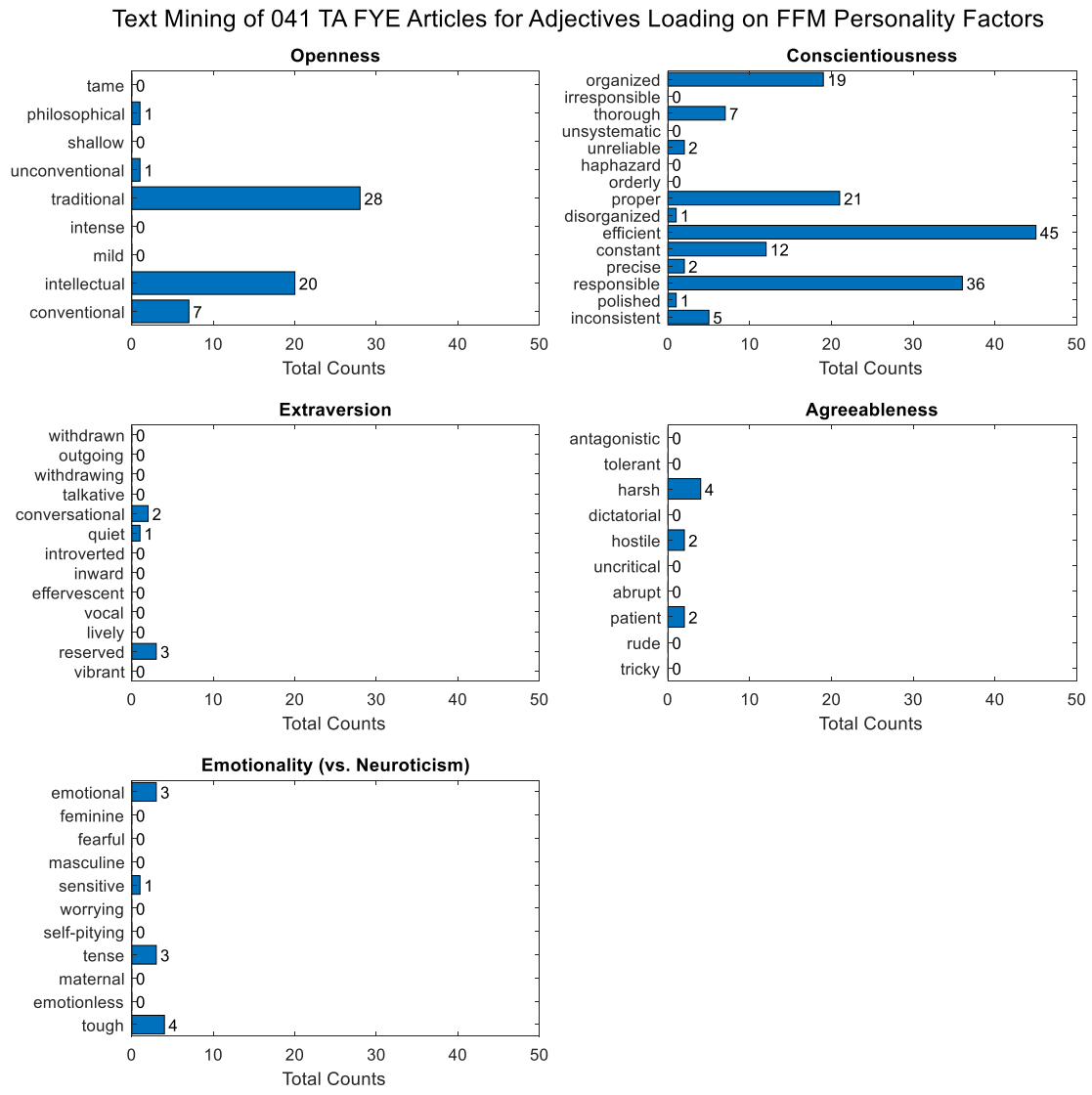

Figure 2: Subplot results for text mining of 41 FYE TA articles for FFM personality-descriptive adjective counts.

Discussion

The adjective counts results from the two sets of articles suggest that there may be some prevalence of personality type terms in TA literature. Over 90% of the articles in each set had at least some presence of personality-descriptive adjectives.

In both the full set of STEM articles and the subset of FYE articles, the factor with the largest number of different personality-descriptive adjectives and the largest number of counts of adjectives is Conscientiousness. The most common words in this factor are *organized*, *proper*,

efficient, *constant*, and *responsible*. This may suggest that literature authors are reporting on the important purpose, accomplishments, and reliability of TAs in STEM courses.

The factor with the second-largest number of different adjectives and corresponding counts is Openness. This factor includes the potentially overly-represented adjective *traditional*, and the other most common adjectives are *intellectual*, *conventional*, and *philosophical*. Although the term *intellectual* may be used to describe the knowledge and creativity of TAs in helping students, the other two common terms may evoke other uses for things other than TA personality.

The remaining three factors, Extraversion, Agreeableness, and Emotionality (vs. Neuroticism) all had much lower numbers of different adjectives and corresponding counts. Within Extraversion, the most common terms are *quiet* and *reserved*, which may refer to TA personality or to student personality. Within Agreeableness, the most common terms are *patient* in both sets and also *rude* in the full set. It would be interesting to investigate more closely under what circumstances the term *rude* is used. Within Emotionality, the most common terms are *emotional*, *sensitive*, and *tense*. All three of these may refer to TA personality.

Broadly, FYE programs may empower TAs to accomplish tasks reliably with a higher level of importance than STEM education courses. This notion is supported by the Conscientiousness factor counts percentage of total for FYE TA articles being much higher than that for all STEM articles. This higher percentage of Conscientiousness factor counts percentage for FYE TA articles may corroborate with the findings from Hall, et al., (2015) that higher levels of Conscientiousness increase student success and retention. Because first-year engineering courses put emphasis on student success and retention, TAs may develop higher Conscientiousness through their own student experiences or through pedagogical training which come across in the FYE TA literature. This would support the notion that TA personality factors have an influence on the success of students in FYE and possibly STEM courses in general.

Limitations and Future Work

A major limitation of the text mining process used here is that the results are simply counts of matched words found anywhere within the acquired documents. This removes the context associated with the terms and makes it difficult to determine how many of these counts actually correspond to reference to personality as opposed to other uses of the words. A more sophisticated method of analyzing articles for particular terms and extracting more conceptual and contextual understanding is being developed for future analysis.

Although these results show there is some prevalence of personality type terms in TA literature, the level of importance of these factors is not clear from this analysis. Therefore, future work will include further investigation into how students and TAs perceive personality behaviors in the classroom and how those behaviors can be measured and adapted to enhance TA instruction for students. Nonetheless, this study demonstrates that personality factors do appear in STEM and FYE TA literature and that some TA personality factors may be linked to student success and retention in FYE and STEM.

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