International Journal of Engineering Education Vol. 37, No. 1, pp. 44–64, 2021
Printed in Great Britain
0949-149X/91 $3.00+0.00

Testing the Civic-Minded Graduate Scale in Science and Engineering*

JUSTIN L. HESS
Purdue University, West Lafayette, IN, USA. E-mail: jhess@purdue.edu

ATHENA LIN
Purdue University, West Lafayette, IN, USA. E-mail: lin1157@purdue.edu

GRANT A. FORE
IUPUI, Indianapolis, IN, USA. E-mail: gfore@iupui.edu
University of Cape Town, Cape Town, South Africa.

TOM HAHN
IUPUI, Indianapolis, IN, USA. E-mail: tomhahn@iupui.edu

BRANDON SORGE
IUPUI, Indianapolis, IN, USA. E-mail: bsorge@iupui.edu

Education is a prominent modality for preparing the future workforce to engage as ethical practitioners in their future careers and as good citizens within society. Thus, we need contextually valid ways of measuring individual's civic growth in higher education, especially in US engineering education where ethics is a required component for accreditation. The primary objective of this study was to test and validate the Civic-Minded Graduate (CMG) Scale, an increasingly used measure of civic-mindedness outside of STEM, with science and engineering students. In Phase 1, we used principal component analysis to identify a potential factor structure of the CMG Scale based on responses from 434 first-year engineering students. In Phase 2, we utilized confirmatory factor analyses and sought to confirm the Phase 1 extracted solution with two distinct student samples. Based on these analyses, we were able to extract and confirm a five-factor CMG solution. The novel factors included: (1) Valuing Community Engagement, (2) Confidence in Building Consensus, (3) Civic Knowledge and Skills, (4) Empathic Interpersonal Communication, and (5) Civic Intentions and Obligations. In the discussion, we unpack what these novel constructs represent. In addition, we argue for their alignment with broader considerations in science and engineering education research and practice. Finally, we recognize future research that is needed to further solidify these findings.

Keywords: Keywords: civics; civic mindedness; quantitative; factor analysis

1. Introduction

The concept of civics arguably traces its roots back to the Ancient Greeks and the work of Aristotle [1]. In *Nichomachean Ethics*, Aristotle describes what it means to be a good citizen, including what virtues one will seek to cultivate and how one ought to engage in society. In *Politics*, Aristotle further discusses the relationship between the citizen and the city, the city being "a community of citizens in a regime" [2]. Thus, the city arises from its citizens, the citizens play a role in the functioning of said city, and both city and its members affect one another.

While Aristotle did not explicitly utilize the term "civics," his focus on the development of certain virtues resembles modern day uses of the term civic virtue. For example, Ramaley [3] defined civic virtue as "both knowledge of the public good and the sustained desire to achieve it" (p. 228). Likewise, Podsakoff, et al. [4] defined "civic virtue" in the context of the organization as, "Behavior on the part of an individual that indicates that he/she responsibly participates in, is involved in, or is concerned about the life of the company." Thus, civic virtue describes the role and obligations of the self within and in relation to a broader system. In Podsakoff et al.'s [4] case, the system was the organization, but other systems might include a family, city, nation, religion, or profession, to name a few examples.

Conversations of civics and civic virtue inevitably tend towards the political domain. For Aristotle, the highest individual virtues involve seeking excellence through politics, wherein "politics, properly understood [in Aristotle's sense], is form or order consciously maintained and occasionally reformed for the sake of forming the best human beings" [2]. For Aristotle, the city manifests from a "political order." In other words, "the way in which a multitude of human beings orders itself or maintains an order is the definitive cause of the city" (p. 417).

Education serves as a primary modality for preparing individuals to function in society. In American discourses, Dewey [5] is often recognized for revitalizing the modern focus pertaining to the

* Accepted 12 July 2020.

role of education in preparing individuals to engage in a democratic society. To this end, Dewey speaks of "civic efficiency" as "good citizenship," which recognizes "the fact that the things which most need to be done are things which involve one's relationships with others." Thus, for Dewey, "civic activity and civic excellence need the help of others; one cannot engage in public life all by himself [sic.]." Moreover, the role of education is to support individual growth towards a democratic way of living. As Hansen [6] describes:

> "For Dewey, democracy constitutes something richer and more generative than its electoral process and system of political structures, as valuable as they are. Rather, 'democratic life' constitutes another name for a life of inquiring, communicating, and learning. In Dewey's outlook, democracy necessitates learning about many things: other peoples' views and hopes, how to resolve problems as they surface, how to anticipate and plan for possibilities, how to remain modest in one's claims to truth, how to think about what is good for individuals, communities, and society itself, and more. In reciprocal fashion, democracy as a mode of associated living makes possible this very process of interactive learning and understanding."

Thus, in the context of education, Dewey [5] calls for integrated education, wherein considerations such as civics and social responsibility are embedded within their all-too-often de-contextualized technical or scientific content. These considerations bear upon our perceptions of the concept of civic mindedness, particularly when we situate this concept in the context of science and engineering education. Civic mindedness calls forth considerations of how one ought to engage within one's community and society, the relationships amongst various actants therein, and the integration of multiple considerations which are often disentangled from the engineering discourse (e.g., politics, ethics). In agreement with Dewey, we theorize that education serves as the primary modality for preparing students to engage as good members of a democratic society. Given this goal, we recognize a need for contextually valid ways of measuring individual's civic growth in higher education.

2. Study Purpose

The primary objective of this study was to test and assess the structural validity of the Civic-Minded Graduate (CMG) Scale with science and engineering students. The study is comprised of two phases. The first phase seeks to identify a potential factor structure of the CMG via principal component analysis when utilized with first-year engineering students. The second phase seeks to confirm these findings through confirmatory factor analyses among two student samples (note: one sample includes many of the same respondents from Phase 1 but who completed the survey at a different time point). The outcomes of this investigation will enable us to evaluate the structural validity of the CMG Scale when utilized with science and engineering students, as well as additional considerations for measuring civic mindedness in engineering in a contextually valid manner.

3. Literature Review

This literature review is comprised of three parts. First, we explore prior efforts at assessing civic-related outcomes in higher education. Second, we provide an overview of the CMG Scale and prior validation studies. Finally, we briefly summarize the review.

3.1 Measuring Civic Outcomes in Higher Education

Assessments of civic learning outcomes may focus on civic knowledge, skills, attitudes or behaviors. One way to distinguish assessments is *civic competencies* versus *civic engagement* [7]. Assessments focused on civic competencies tend to feature knowledge items (e.g., civic principles, government, and democracy) as well as civic skills that support active engagement in a community (e.g., dialogue, interpersonal perspective taking, critical thinking) [see 7, 8]. By contrast, assessments focused on civic engagement are more concerned with civic values, attitudes, and behavioral intentions, such as open-mindedness, empathy, and diversity [7, 8].

Most research on civic outcomes in higher education has examined non-behavioral outcomes, such as knowledge, skills, and attitudes [9]. While civic knowledge and skills can potentially be observed or measured directly, civic attitudes generally, but not exclusively, rely on self-report measures [10]. For example, the Center for Service and Learning at Indiana-University-Purdue University Indianapolis (IUPUI) operationalized three related measures for assessing the civic-minded graduate: (1) a 30-item self-report instrument, (2) an interview protocol, and (3) a narrative prompt [11–13]. Of these three strategies, the 30-item Civic-Minded Graduate Scale or CMG Scale [11] has become the most oft-used measure of civic-learning.

The CMG Scale was designed to measure a sampling of civic outcomes that exemplify the qualities of a "civic-minded graduate," or someone who graduates from higher education with the "capacity and desire to work with others to achieve the common good" [11]. In this framework, civic-mindedness can be understood as "a person's inclination or disposition to be knowledgeable of and involved in the community, and to have a commitment to act upon a sense of responsibility as a member of that community" [11]. This definition of civic-mindedness encompasses civic knowledge, dispositions, skills, and behaviors [13]. These a priori operationalizations underpin the design of the CMG Scale and thus underlie the factor analyses employed in this study.

3.2 CMG Scale Validation Studies

To assess the construct validity [14] of the CMG Scale, including its domains and subdomains, researchers have conducted factor analyses and compared CMG responses to other scales measuring related constructs.

Steinberg et al. [11] first conducted factor analysis on the CMG Scale with a sample size of 86 participants. The extracted factor solution suggested a single factor accounting for 45.7% of the variance. They considered this single factor to be a measure for civic mindedness. Steinberg et al. [11] conducted another factor analysis with a larger sample size of 606, wherein their findings further supported a one-factor solution that accounted for 49.4% of variance. Based on these two analyses, Steinberg et al. [11] concluded that the CMG Scale is unidimensional. Next, Steinberg, et al. [11] qualitatively grouped items into the four domains and sub-domains described above. Today, these ten domains are often utilized in CMG studies [15, 16].

In addition to factor analyses, many studies of the CMG Scale domains and subdomains have sought convergent validity by ascertaining correlations with other validated studies. For example, since civic-mindedness is considered a positive attribute, the research team tested for social desirability bias in the responses using the Marlow-Crowne Social Desirability Scale. They found a nonsignificant correlation between students' responses to the CMG Scale and the Marlow-Crowne scale, providing positive evidence of construct validity [17].

Bringle and Wall [15] administered the CMG Scale alongside four other instruments, including the Volunteer Functions Inventory, Civic Identity Scale, Student Identity Scale, and Morton's Typology of Service Scale. With a sample size of 132 participants, Bringle and Wall [15] conducted bivariate correlations and found that the CMG Scale correlated strongly with the Civic Identity Scale, interest in service programs, interest in advocacy for social change, and three subscales of the Volunteer Functions Inventory: Protective, Values, and Understanding. They found weak correlations between the CMG Scale and the Student Identity Scale.

In another study, Bringle, et al. [16] administered a questionnaire with the CMG Scale and four additional scales: the Openness to Diversity and Challenge Scale, Charity Scale and Social Change Scale, Self-Efficacy Scale, and Principle of Care Scale. Bringle, et al. [16] conducted bivariate correlations and found large positive correlations between the CMG Scale and openness to diversity, interest in social change, and interest in volunteering through charity. They found moderate correlations between the CMG Scale and the remaining scales, including principles of care and self-efficacy.

Taken together, the studies by Bringle and Wall [15] and Bringle et al. [16] provide supportive evidence that the CMG Scale is correlated with students' interest and motivation for service, as measured in the Volunteer Functions Inventory, Morton's Typology of Service Scale, and Charity Scale. In addition, the findings from Bringle and Wall [15] suggest a correlation between the CMG Scale and students' attitudes towards diversity. While we did not employ similar convergent validity checks in this study, we would posit that the factors of a novel factor structure, being comprised of the same underlying items, would exhibit similar correlations as these past studies.

3.3 Summary of Literature Review

As civic attitudes can be quite broad in scope, measures of civic attitudes are often multi-faceted [7]. Measurements of civic mindedness may distinguish between civic competencies and civic engagement. The CMG predominantly focuses on the latter, specifically on knowledge, skills, dispositions, or behaviors. Prior validation work on the CMG Scale has focused on providing evidence of construct validity by comparing the CMG Scale to related scales. Consequently, there is a gap in additional validation work on the ten-domain factor structure of the CMG Scale. Notably, in the recent studies by Bringle and Wall [15] and Bringle et al. [16], the CMG Scale was treated as unidimensional in the bivariate correlation analyses. Also, no prior validation studies uniquely focused on science and engineering students. Thus, taken together, these present a need to ascertain the factor structure of the CMG when situated in science and engineering.

4. Research Design

In this study, we utilized the Civic-Minded Graduate (CMG) Scale [11]. In its original design, CMG Scale items were grouped into four domains, each with one to three sub-domains: (i) Knowledge – Volunteer Opportunities (KVO), Academic Knowledge and Technical Skills (KAK), and Contemporary Social Issues (KCSI); (ii) Skills – Listening (SL), Diversity (SD), and Consensus-Building Skills (SCB), (iii) Dispositions – Valuing Community Engagement (DVCE), Self-Efficacy (DSE), Social Trustee of Knowledge (DSTK), and (iv) Behavioral Intentions (DBE). Appendix A provides a summary of survey items by subdomain.

Our initial objective in this study was to confirm the pre-defined sub-domains of the CMG. However, when we sought to confirm the structure of these subdomains using Confirmatory Factor Analysis procedures [18, 19], we found that the factor structures for each subdomain did not hold. Thus, we theorized that an underlying latent factor structure might be distinct among engineering and science students in comparison to the four subdomains specified by Steinberg et al. [11]. Based on this theory, this study begins with a Principal Component Analysis, or PCA, which seeks to identify a potential factor structure of the CMG. Phase 2 seeks to confirm the Phase 1 findings.

4.1 Participant Overview

We disseminated the CMG to two large public midwestern Universities. Surveys were disseminated through select courses. For University 1, we disseminated the CMG Scale to first-year engineering students at the beginning and end of the Fall 2019 academic semester. Participants were from one of five sections of an introductory engineering course. University 1 participants received extra credit worth up to 1% of their course grade. University 1 participants included 485 participants total, which includes 419 students who completed the survey at the start of the semester and 434 students who completed the survey at the end of the semester. Phase 1 of this study utilizes the beginning-of-semester responses and Phase 2 Part 1 utilizes the end-of-semester responses. In addition, Phase 2 Part 2 of this study includes students enrolled in a Biomedical Engineering or Earth Science course at a distinct university (University 2) in the Fall 2017, Spring 2018, or Fall 2019 semester. Table 1 summarizes participants by University.

5. Phase 1. Principal Component Analysis

5.1 Overview

This phase addresses the research question, "What

Table 1. Overview of Participants for Phase 1 (PCA) and Phase 2 (CFA1 and CFA2)

Demographic Item	**University 1**	**University 2**
Total Participants	485*	420
School		
Engineering or Engineering & Technology	390	169
Science	0	130
Other	3	64
Undecided, Not Declared, or Not Specified	41	57
Academic Standing		
Freshman	378	66
Sophomore	23	74
Junior	15	87
Senior	0	142
Graduate	0	6
Not Declared or Not Specified	18	45
Sex		
Male	312	174
Female	104	205
Other Sex or Not Declared	18	41
Race/Ethnicity (participants may select multiple)		
American Indian or Alaska Native	2	0
Asian	117	12
Black or African American	12	16
Hispanic or Latino	28	13
Native Hawaiian or Pacific Islander	2	0
White or Caucasian	277	281
Other Race/Ethnicity	4	31
Multi-Racial	33	19
Not Declared or Unknown	15	43
Age (*M, SD*)	18.4, 0.62	21.6, 4.3

* University 1 includes students who completed either the first or second survey. However, demographic data was only collected at the end of the Fall 2019 semester. Hence, we are missing demographic data for 66 respondents from University 1.

is a potential factor structure of the Civic Minded Graduate Scale when utilized with first-year engineering students?" To address this question, we utilized Principal Component Analysis, or PCA. PCA is a type of exploratory factor analysis utilized to reduce a set of items to a subset of components or potential factors. As Tabachnick and Fidell [19] state, "The goal of PCA is to extract maximum variance from the data set with each component" (p. 688). To do this, "Principal component analysis uses the correlations among the variables to develop a small set of components that empirically summarizes the correlations among the variables" (p. 57). More specifically, PCA proceeds stepwise, with the first component extracted striving to maximize variation (i.e., variance) captured by a component. Each next component extracted utilizes the residual correlations and seeks to extract "maximum variability uncorrelated with the first component" (p. 688).

Some authors have suggested that PCA is the most common type of EFA [18, 20], but PCA is distinct from factor analysis [19]. The primary distinction is in the diagonal of the correlation matrix, or the correlation between a given factor with itself. In PCA, the correlation between a factor and itself is assumed to be 1.0, thereby distributing all variance to components, "including error and unique variance for each observed variable" (p. 687). In contrast, in factor analysis the "variance that each observed variable shares with other observed variables is available for analysis," and this is estimated by communalities (p. 687). Communalities, representing shared variance, are inserted into the diagonal and utilized to derive the factor structure. As Tabachnick and Fidell [19] state succinctly, "PCA analyzes variance; FA [factor analysis] analyzes covariance (communality)" p. 688).

While variants of EFA exist, some scholars have suggested that when a study contains a large set of survey items (i.e., more than 30) and when many communalities of the derived factor structure exceed 0.60, the results tend to be similar whether one utilizes PCA or a variant EFA [20]. Likewise, Tabachnick and Fidell [19] advise, "PCA is the solution of choice for the researcher who is primarily interested in reducing a large number of variables down to a smaller number of components" (p. 688). In this study, we utilized PCA, but post-hoc, we also checked the PCA extracted solution with a principal axes factor analysis solution and found that the extracted solutions were similar. We utilized Stata/IC 16 for all computations.

5.2 Validation Considerations

Instrument validation is an iterative and ongoing process. As Douglas and Purzer [21] state, "Validity is never quite over. It is a goal we strive for, but given the nature of educational variables, the process of reevaluating the appropriateness of an instrument's use is **ongoing**" (p. 111, emphasis from original article). Messick [14] identified six distinct aspects of construct validity that, taken together, support the construct validation process, including: (1) content, (2) substantive, (3) structural, (4) generalizability, (5) external, and (6) consequential. Douglas, et al. [22] expounded upon these validity aspects in the context of engineering education, including types of research questions and associated evidence for each aspect. Structural validation checks are accomplished through factor analysis and address questions such as, "Is the internal structure of the instrument congruent with the structure of the construct domain?" (p. 1963).

Hence, in this work, we are not validating the CMG Scale. Rather, we are looking at one aspect (i.e., structural validity) of the broader construct validation process. Findings from this structure (e.g., a novel factor structure of the CMG Scale) neither supports nor undermines the validation approaches from prior CMG Scale validation studies. The derived factor structure may not be unidimensional as in the Bringle and Wall [15] or Bringle, et al. [16] studies; rather, these findings clarify the nature of the conceptual domain underlying the scale *within the context of* engineering and science education at two large public mid-western universities in the United States.

5.3 PCA Assumptions

Prior to conducting PCA, we checked pertinent assumptions regarding the potential factorability of the data. First, respondents must have answered all questions before proceeding with the survey. Hence, there was no missing data. Second, we checked the number of participants per question. Nunnally [23] suggested that PCA include 10 respondents per question. As we had 434 responses to 30 questions, we had 14.5 participants per question, thus meeting this assumption. Third, we checked skewness and kurtosis values of individual variables for multivariate normality and we found that all variables were approximately non-normal. Despite this non-normality, we proceeded with analysis, although we recognize this as a potential weakness of the derived factors. In the subsequent CFAs, we control for normality issues. Fourth, we checked linearity among pairs of variables. As there were 30 variables, we only reviewed scatterplots for a subset of 15 randomly selected variable combinations. All combinations appeared linear, thus enhancing our confidence in the PCA output. Fifth, we checked individual variables for outliers, defining outliers as falling three standard deviations from the average response to a variable. This led to the removal of 32 responses, thus retaining 402 responses for PCA. Note, we still had 13.4 participants per question due to outlier removal. Normality improved, with six of 30 variables being approximately normal after removing outliers, thus further improving our confidence in the removal of these responses.

Next, we computed the inter-item correlation matrix of the remaining 402 observations. Most inter-item correlations (241 out of 435, or 55.4%) were greater than 0.30 (see Appendix D), thus supporting factorability of the data (see Tabachnick & Fidell, 2014, p. 667). Fourth, we computed the Kaiser–Meyer–Olkin [24] coefficient. The average KMO for CMG items was 0.92, thus suggesting that the data factorability was "marvelous." Fifth, we calculated Bartlett's test for sphericity. This value was significant ($p < 0.001$) thus further supporting data factorability. Finally, to determine the appropriate rotation, we started by applying an oblique rotation, direct oblimin with a delta of 0, which is equivalent to a "direct quartimin" rotation [19]. Next, we checked the factor correlation matrix. As many inter-factor correlations were above 0.32, this decision was warranted, as this suggests "there is 10% (or more) overlap in variance among factors, enough variance to warrant oblique rotation" [19].

5.4 PCA Factor Retention

First, we applied the eigenvalue rule to ascertain the appropriate number of components. This potentially suggested a six-component solution that explained 60.9% of the variance, although Component 6 was on the cut-off threshold with an eigenvalue = 1.00. Second, we utilized "Monte Carlo PCA for Parallel Analysis" (Ed & Psych Associates 2011) as a further check. Comparing the actual eigenvalues with the parallel eigenvalue criterion suggested a four-component solution (i.e., Component 5 eigenvalue of 1.19 is less than the parallel criterion value of 1.32, see Table 2). Third, we considered the variance explained by a four, five, and six factor solutions. As the five-factor solution adds 4.0% explanatory power, and as this was near the parallel criterion cutoff but well above the eigenvalue rule threshold of 1.0, we opted to continue with the five-factor solution. Table 2 shows the actual eigenvalues, the proportional and cumulative variance explained, and the parallel criterion.

Afterwards, to further check these decisions, we computed and checked the potential component items and the pattern coefficients of items on the five potential components. Pattern coefficients above 0.50 are considered "strong" [25]. In the five-component solution, one pattern coefficient was greater than 0.50, and 10 additional pattern coefficients were above 0.40. In contrast, the potential four-factor solution did not contain any pattern coefficients above 0.50 and only seven pattern coefficients above 0.40. This final check solidified our decision for a five-factor solution.

5.5 Results

The output of the PCA includes the variance explained by principal components (i.e., potential factors) in rotated and unrotated matrices, an unrotated set of principal components and associated item loadings, and a rotated set of principal components and associated item loadings. Appendix E shows the output of the unrotated factor solution. In the rotated solution, component 1 explained 13.5% of the variance, component 2 explained an additional 12.5%, component 3 explained 11.8%, component 4 explained 10.0%, and component 5 explained 9.6%. In total, these five components explained 57.5% of the variation in participants responses to the 30-items from the original CMG.

Table 3 summarizes the component loadings (i.e., the correlation of individual items and the extracted principal component), as well as the total amount of unexplained variance for individual items based on the extracted principal components. Note that the unexplained variation is equal to the sum of squares of loadings that were removed. Many loadings suggested a moderate relationship (i.e., above 0.30) between the item and the component and only a few loadings suggest a large or nearly large relationship (i.e., above 0.50).

Based on the rotated solution matrix, we mapped

Table 2. PCA eigenvalues, variance explained by factors, and parallel criterion

Factor	Eigenvalue	Difference	Proportion	Cumulative	Parallel Criterion
Comp1	10.38	8.01	34.6%	34.6%	1.55
Comp2	2.36	0.52	7.9%	42.5%	1.47
Comp3	1.84	0.35	6.1%	48.6%	1.42
Comp4	1.48	0.29	5.0%	53.5%	1.36
Comp5	1.19	0.19	4.0%	57.5%	1.32
Comp6	1.00	0.09	3.4%	60.9%	1.28
Comp7	0.92	0.11	3.1%	63.9%	1.24

Table 3. Principal Components (eigenvectors) in Rotated Solution

#	Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Unexplained
1	KVO_01	0.05	–0.22	0.46	0.08	0.05	31.3%
2	KAK_01	0.01	0.07	0.45	–0.10	–0.11	33.8%
3	SD_01	0.06	–0.06	0.13	0.30	–0.02	57.4%
4	KAK_02	–0.10	0.13	0.39	0.00	–0.02	39.3%
5	BI_01	–0.07	–0.01	0.04	0.08	0.49	32.0%
6	SCB_01	–0.21	0.33	0.18	0.07	–0.01	50.6%
7	KVO_02	0.01	–0.09	0.28	0.17	0.11	50.9%
8	SL_01	–0.04	–0.01	0.06	0.46	0.05	33.1%
9	DSE_01	0.02	0.12	0.24	0.13	–0.08	47.3%
10	KAK_03	0.05	–0.05	0.21	0.21	0.01	56.9%
11	DSTK_01	0.46	–0.09	0.02	0.01	–0.01	29.8%
12	DVCE_01	0.33	–0.01	0.10	–0.04	0.07	33.9%
13	KCSI_01	0.00	–0.02	0.04	–0.04	0.51	24.6%
14	DVCE_02	0.43	–0.08	–0.01	–0.01	0.04	38.0%
15	KVO_03	0.09	0.05	0.26	–0.18	0.09	55.5%
16	SL_02	0.00	0.00	–0.03	0.46	0.05	36.9%
17	BI_02	0.01	0.13	0.01	–0.10	0.37	40.1%
18	SD_02	0.05	0.17	–0.10	0.31	0.00	47.6%
19	BI_03	0.25	0.12	–0.02	–0.04	0.02	58.2%
20	DSTK_02	0.34	0.03	0.01	0.01	0.00	43.3%
21	KCSI_02	0.03	0.29	0.07	–0.24	0.15	42.0%
22	KCSI_03	–0.03	0.20	0.21	–0.19	0.17	45.0%
23	DSE_02	–0.05	0.46	–0.04	–0.06	0.01	42.4%
24	SCB_02	–0.05	0.32	–0.15	0.19	0.11	44.9%
25	DSTK_03	0.33	0.19	–0.07	–0.04	–0.06	38.1%
26	DVCE_03	0.29	0.13	0.03	0.07	–0.12	38.4%
27	DSE_03	0.12	0.37	–0.02	0.00	–0.11	39.7%
28	SCB_03	0.00	0.29	–0.03	0.24	–0.10	44.2%
29	SD_03	0.13	0.11	0.01	0.12	0.07	59.8%
30	DVCE_04	0.10	–0.04	–0.18	0.10	0.45	39.7%

potential items to potential factors (see Table 4). While we recognize that loadings above 0.30 are ideal for consideration in the final factor structure, conservatively, we documented any loadings above 0.20 in Table 4. As a result, we recognized that the factor solutions tested in Phase 2 might require substantive revisions or removal of items, particularly those with weaker loadings.

6. Phase 2. Confirmatory Factor Analyses

6.1 Overview

This phase addresses two research questions. First, "Using the derived exploratory component structure, can we find a structurally robust set of CMG factors for first-year engineering students?" Second, "Are the CMG factor structures confirmed with first-year engineering students acceptable when utilized with a distinct sample of engineering and science students?" While PCA utilizes correlations among variables to identify a potential set of *components*, factor analysis focuses on the structural alignment of measured variables when reduced to a *factor*. As Tabachnick and Fidell [19] explain, "In PCA, all the variances in the observed variables are analyzed. In FA, only shared variance is analyzed; attempts are made to estimate and eliminate variance due to error and variance that is unique to each variable" (p. 662). As with the Phase 1 PCA, we utilized Stata/IC 16 for all computations.

6.2 Validity Considerations

Prior to performing CFA for each of the potential factors, we checked a series of assumptions. CFA assumes that each observed or measured variable (i.e., an individual's response to a survey question) has two causes: the factor (or latent variable) and an error term. The primary assumption for CFA is that each potential factor includes at least three measured variables. Based on the PCA results from Phase 1, potential factors included between four and eight potential items (i.e., items with factor loadings above 0.20 on a respective component),

Table 4. Overview of Potential Factor Groupings Based on Principal Component Analysis

#	Item	Item Description	Coefficient
1	DSTK_01	I want to dedicate my career to improving society.	0.46
	DVCE_02	I would say that the main purpose of work is to improve society through my career.	0.43
	DSTK_02	I feel a deep conviction in my career goals to achieve purposes that are beyond my own self-interest.	0.34
	DVCE_01	I like to be involved in addressing community issues.	0.33
	DSTK_03	I believe that I have a responsibility to use the knowledge that I have gained to serve others.	0.33
	DVCE_03	I have a sense of who I am, which includes a sincere desire to be of service to others.	0.29
	BI_03	I intend to be involved in volunteer service after I graduate.	0.25
2	DSE_02	I am convinced that social problems are not too complex for me to help solve.	0.46
	DSE_03	I believe that having an impact on community problems is within my reach.	0.37
	SCB_01	I have often been able to persuade others to agree with my point of view.	0.33
	SCB_02	Other students who know me well would describe me as a person who can discuss controversial social issues with civility and respect.	0.32
	KCSI_02	I am prepared to write a letter to the newspaper or community leaders about a community issue.	0.29
	SCB_03	When members of my group disagree on how to solve a problem, I like to try to build consensus.	0.29
3	KVO_01	I know a lot about opportunities to become involved in the community.	0.46
	KAK_01	I am able to plan or help implement an initiative that improves the community.	0.45
	KAK_02	I have the professional knowledge and skills that I need to help address community issues.	0.39
	KVO_02	I am very familiar with clubs and organizations that encourage and support community involvement for college students.	0.28
	KVO_03	I would say that most other students know less about community organizations and volunteer opportunities than I do.	0.26
	DSE_01	I can contribute to improving life in my community.	0.24
	KAK_03	I feel confident that I will be able to apply what I have learned in my classes to solve real problems in society.	0.21
	KCSI_03	I am aware of a number of community issues that need to be addressed.	0.21
4	SL_02	I am a good listener, even when peoples' opinions are different from mine.	0.46
	SL_01	I listen to others and understand their perspective on controversial issues.	0.46
	SD_02	I am able to respond to others with empathy, regardless of their backgrounds.	0.31
	SD_01	I appreciate how my community is enriched by having some cultural or ethnic diversity.	0.30
	SCB_03	When members of my group disagree on how to solve a problem, I like to try to build consensus.	0.24
	KAK_03	I feel confident that I will be able to apply what I have learned in my classes to solve real problems in society.	0.21
5	KCSI_01	I stay up to date on the current political issues in the community.	0.51
	BI_01	I intend to stay current with the local and national news.	0.49
	DVCE_04	It is important for me to vote and be politically involved.	0.45
	BI_02	I plan to participate in advocacy or political action groups after I graduate.	0.37

thus meeting this assumption. Table 4 shows an overview of potential items per each factor. As Table 4 shows, one item (SCB_03) potentially loaded onto multiple factors. We tested model variations based on this finding. Second, we checked data for normality. As most statistics were approximately non-normal, we utilized a Satorra-Bentley (SB) modification. Third, we checked for outliers. We found 31 outliers, which we defined as responses falling outside of 3 standard deviations on any individual variable. We chose to retain outliers for statistical power concerns, but post-hoc, we checked the factor solutions with and without outliers.

We checked the sample size with the remaining data and its alignment with statistical power concerns. We used suggested cutoffs for a statistical power of 0.80 [26]. Our most complex model included eight observed variables and 20 degrees of freedom, which requires 435 participants. Hence, we note that we are near but have slightly less statistical power than the sought 0.80 threshold in our most complex model. Importantly, as we remove variables, the degrees of freedom in the model declines, which corresponds with a reduction in statistical power. For example, a model with 10 degrees of freedom requires 782 participants for a statistical power of 0.80.

We utilized model-fit statistics and cutoff criteria based on a literature synthesis by Schreiber, et al. [27]. The first, and primary test of interest was the chi-square test and the associated level of significance. The objective in analysis is to *fail* to reject the null hypothesis of the chi-square (χ^2) test, as this hypothesizes that data are significantly different from the constructed model. Second, we sought a Tucker- Lewis Index (TLI) greater than 0.95 and a root mean square error approximation (RMSEA) statistic less than 0.08 (or more ideally, below 0.06). Given the non-normality assumption, all statistics that we report are SB-modified.

While we assume error terms are independent, when seeking improved model fit, we can more closely scrutinize variables and test potential interdependence (i.e., correlation) of error terms. In turn, we can see if correlating error terms leads to an improved model fit. This re-evaluation begins with a re-examination of the chi-squared statistic in any new model when compared to its predecessor, followed by other fit indices. As Schreiber et al. [27] state, "If a model has been modified and reanalyzed, one should provide evidence that the modified model is statistically superior to the original model with a chi-square test" (p. 327).

Potential validity concerns arise when we make significant model revisions, specifically as it enhances the likelihood of committing a Type I error. As Tabachnick and Fidell [19] state, moderate revisions to a factor structure is navigating towards *exploratory* factor analysis techniques, and "appropriate steps need to be taken to protect against inflated Type I error levels" (p. 737). In such instances, they recommend that "significance levels are viewed cautiously and cross-validation with another sample is performed" (p. 737). Hence, we seek to reduce concerns of the low sample size and statistical power in these measurement models by cross-validation of findings with two samples. Furthermore, by conducting a CFA with many of the same participants but at a different time point, we will be seeking *internal* replicability; by cross-validating these findings with a distinct set of participants, we will be seeking *external* replicability [18].

6.3 Results

In this section, all factor loadings displayed represent standardized coefficients. Hence, in each measurement model (Figs. 1–5), the values associated with arrows moving from a latent variable to an item represent changes in standard deviations rather than changes along the original nine-point Likert type-scale on which items were posed. Standardization of items allows us to see the relative impact of individual items on factors and allows direct comparison with other standardized measurement models employed by other researchers but with different scaling procedures (note, in our use of the CMG we utilized a 9-point Likert-type scale where 1 represented strong disagreement and 9 represented strong agreement). In addition, we report chi-squared (χ^2) statistics, degrees of freedom (*df*), significance level (*p*), the Root Mean Square Error Approximation (RMSEA), 90% Confidence Interval (CI), and the Tucker Lewis Index (TLI). All statistics are Satorra-Bentley modified (SB) due to concerns of non-normality.

<u>*Factor 1*</u>

We initially generated a CFA model estimating Factor 1 that included all seven potential items (see Table 4). The model fit was unacceptable, χ^2 (14) = 73.08, p < 0.01, RMSEA = 0.100, 90% CI [0.109, 0.153], TLI = 0.929. Hence, we removed items with the smallest factor loading stepwise until the model fit the specified objectives. First, we removed BI_03, and the model improved but remained unacceptable, χ^2 (9) = 32.16, p < 0.01, RMSEA = 0.078, 90% CI [0.077, 0.133], TLI = 0.965. Next, we removed DSTK_02; the model slightly improved but remained unacceptable, χ^2 (5) = 27.22, p < 0.01, RMSEA = 0.103, 90% CI [0.090, 0.164], TLI = 0.957. Finally, we removed DVCE_03 and achieved an acceptable model fit, χ^2 (2) = 0.67, p = 0.72, RMSEA < 0.01, 90% CI [0.000, 0.077], TLI = 1.005. We sought to reproduce these findings with students from University 2, and again reached an acceptable model fit, χ^2 (2) = 0.04, *p* = 0.98, RMSEA < 0.01, 90% CI [0.000, 0.000], TLI = 1.010. Fig. 1 shows a graphical depiction of results from both analyses.

<u>*Factor 2*</u>

We initially generated a CFA model estimating Factor 2 that included all six potential items (see Table 6). The model fit was unacceptable, χ^2 (9) = 49.29, p < 0.01, RMSEA = 0.103, 90% CI [0.103, 0.158], TLI = 0.879. First, we removed KCSI_02 and found that all fit indices improved, χ^2 (5) = 19.6, p < 0.01, RMSEA = 0.084, 90% CI [0.114, 0.188], TLI = 0.935. Next, we correlated error terms between DSE_02 and DSE_03, and the model was still unacceptable, χ^2 (4) = 9.78, p = 0.044, RMSEA = 0.059, 90% CI [0.034, 0.122], TLI = 0.959. Finally, we correlated error terms between SCB_01 and SCB_03 and we reached an acceptable solution, χ^2 (3) = 4.49, p = 0.21, RMSEA = 0.034, 90% CI [0.000, 0.105], TLI = 0.989. Using the same factor structure, we were able to find an acceptable model fit with University 2 students, but we found that the correlations between error terms were non-significant. Hence, we removed these from this model, and found improved model fit: χ^2 (5) = 7.87, p = 0.16, RMSEA = 0.055, 90% CI [0.006, 0.098], TLI = 0.973.

Post-hoc, we found that Factor 4 required SCB_03. Thus, we removed SCB_03 from Factor 2. We were able to receive a robust solution with

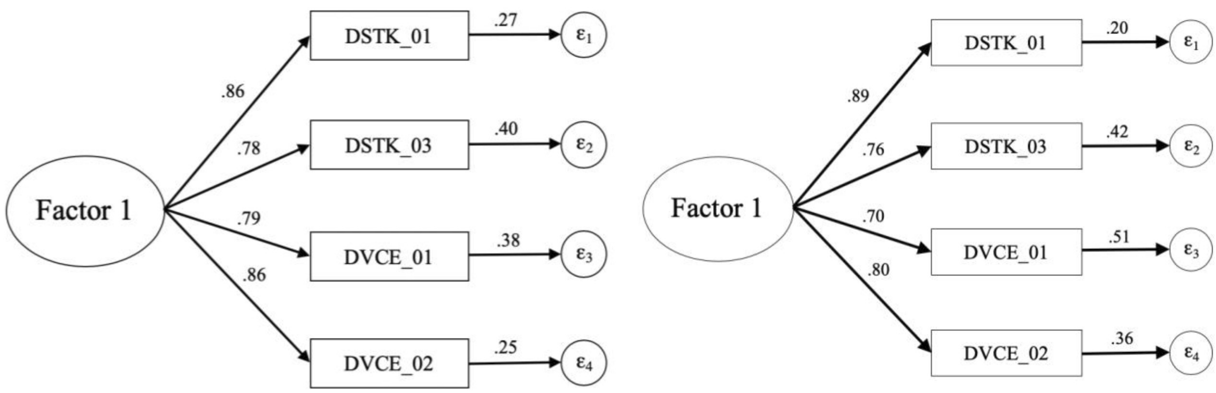

Fig. 1. CFA Models estimating Factor 1 with first-year engineering students (left) and students enrolled in engineering and science courses at a distinct university (right).

University 1 with the inter-error correlation between DSE_02 and DSE_03 retained, χ^2 (1) = 1.86, p = 0.17, RMSEA = 0.045, 90% CI [0.000, 0.159], TLI = 0.982. We were able to replicate the model with University 2, here with the inter-error correlation removed, χ^2 (2) = 1.62, p = 0.44, RMSEA = < 0.01, 90% CI [0.000, 0.102], TLI = 1.004. Fig. 2 shows these final measurement models estimating the latent variable, Factor 2.

Factor 3

We began by generating a CFA model estimating Factor 3 that included all six potential items (see Table 6). The model fit was unacceptable, χ^2 (20) = 96.49, p < 0.01, RMSEA = 0.096, 90% CI [0.101, 0.139], TLI = 0.885. We removed KCSI_03; the χ^2 statistic slightly improved χ^2 (14) = 70.45, TLI improved (0.898) but RMSEA slightly worsened (0.098). Hence, we opted to keep KCSI_03 out of the solution. Next, we removed KVO_03 and the χ^2 statistic and TLI improved but the RMSEA substantially worsened, χ^2 (9) = 57.37, p < 0.01, RMSEA = 0.113, 90% CI [0.118, 0.173], TLI = 0.904. Hence, we chose to retain KVO_03 in the model. We next removed DSE_01, and the model was still unacceptable, χ^2 (9) = 45.79, p < 0.01, RMSEA = 0.099, 90% CI [0.096, 0.151], TLI = 0.913. Next, we removed KVO_02; model indices improved but remained unacceptable, χ^2 (5) = 36.16, p < 0.01, RMSEA = 0.122, 90% CI [0.087, 0.161], TLI = 0.934. Next, we correlated error terms between KAK_02 and KAK_03 and the model improved and was nearly acceptable, χ^2 (4) = 9.60, p = 0.047, RMSEA = 0.058, 90% CI [0.031, 0.119], TLI = 0.974. Finally, we correlated error terms between KVO_01 and KAK_01 and we achieved an acceptable model fit, χ^2 (3) = 5.70, p = 0.13, RMSEA = 0.046, 90% CI [0.000, 0.114], TLI = 0.986. We sought to replicate this model with University students, without correlations between error terms, and we achieved an acceptable model, χ^2 (5) = 8.17, p = 0.15, RMSEA = 0.050, 90% CI [0.000, 0.095], TLI = 0.986.

Factor 4

For Factor 4, we started with 4 of the 6 items from Table 6. We did not initially include SCB_03 as it was included in Factor 2 nor KAK_03 as it was included in Factor 3. The model fit was acceptable, χ^2 (2) = 4.29, p = 0.12, RMSEA = 0.052, 90% CI [0.016, 0.140], TLI = 0.972. Initially, we were unable to reproduce this model with University 2 students, χ^2 (2) = 14.86, p = < 0.01, RMSEA = 0.124, 90% CI [0.131, 0.246], TLI = 0.848. We sought correlating

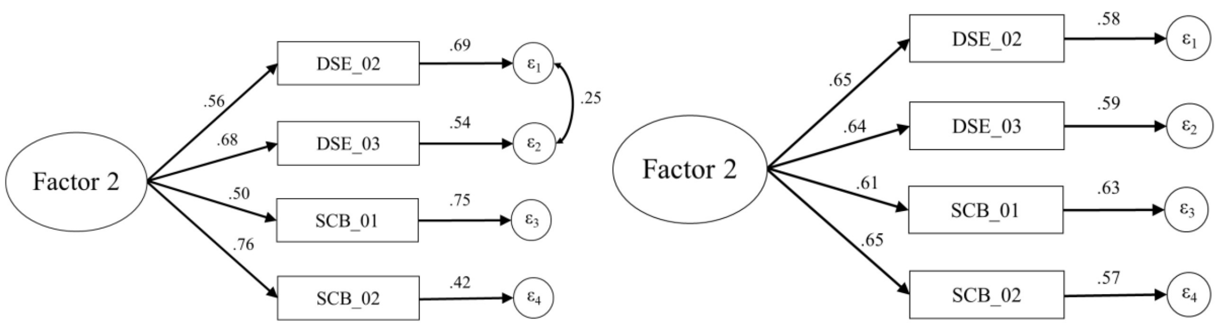

Fig. 2. CFA Models estimating Factor 2 with first-year engineering students (left) and students enrolled in engineering and science courses at a distinct university (right).

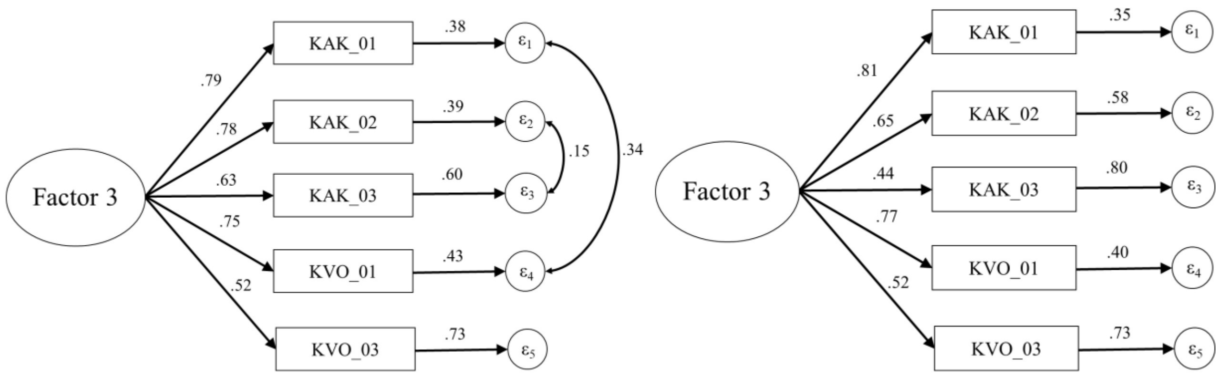

Fig. 3. CFA Models estimating Factor 3 with first-year engineering students (left) and students enrolled in engineering and science courses at a distinct university (right).

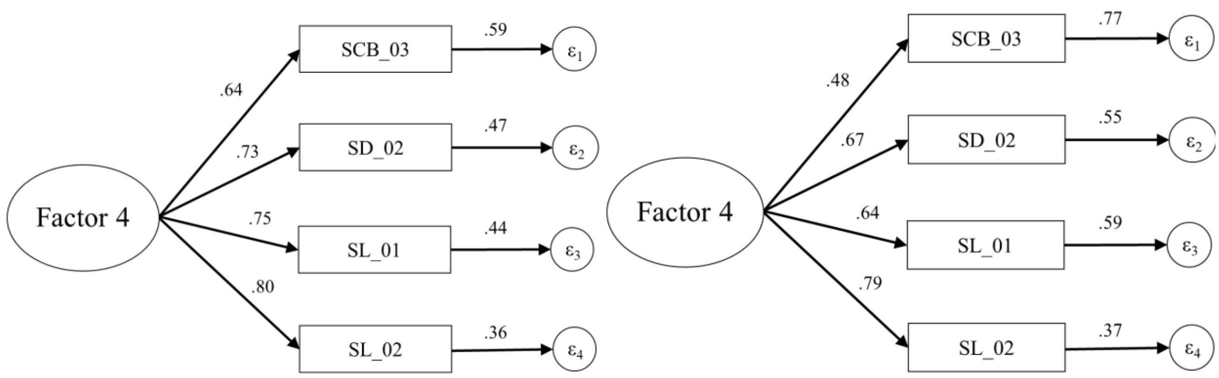

Fig. 4. CFA Models estimating Factor 4 with first-year engineering students (left) and students enrolled in engineering and science courses at a distinct university (right).

error terms and were unsuccessful. Thus, we re-introduced SCB_03 to the model as it was the next the next highest potential item (see Table 4). With the five items, the model fit was still unacceptable. Thus, we removed SD_01 and received an acceptable model fit, χ^2 (2) = 3.22, p = 0.20, RMSEA = 0.050, 90% CI [0.000, 0.120], TLI = 0.983. We revisited the dataset with University 1 students and utilized this new factor structure. We found that the model was acceptable and superior to the initial model, χ^2 (2) = 1.83, p = 0.40, RMSEA < 0.001, 90% CI [0.000, 0.116], TLI = 1.001.

Factor 5

For Factor 5, the PCA results suggested four potential items (see Table 6). With these four items, the model fit was unacceptable, χ^2 (2) = 7.94, p < 0.01, RMSEA = 0.084, 90% CI [0.053, 0.170], TLI = 0.961. Next, we sought to identify similar items. Hence, we correlated error terms between BI_01 and BI_02 and found an acceptable model fit, χ^2 (1) = 0.17, p = 0.68, RMSEA < 0.001, 90% CI [0.000, 0.103], TLI = 1.011. We were able to find an acceptable model fit with University 2 students, χ^2 (1) = 0.12, p = 0.73, RMSEA < 0.01, 90% CI [0.000, 0.091], TLI = 1.011. Importantly, while the error correlations were required to receive a substantive model, this correlation was negative, thus suggesting that the latent variable is not accounting for an unknown (i.e., un-observed) variable. This suggests that Factor 5, while acceptable, might require slight improvements in future use. Fig. 5 shows these final measurement models.

7. Discussion

This study sought to validate the CMG Scale when utilized with engineering and science students. In Phase 1, we began by utilizing principal component analyses (PCA) which suggested a potential five-factor solution. In Phase 2, through slight modifications to the extracted structure in Phase 1, we were able to confirm a five-factor solution with two distinct populations. This discussion features three sub-sections. First, we conceptualize the novel five factor solution by conceptualizing the core construct components and comparing these factors with original CMG subdomains. Second, we contextualize these findings and this study's design with other pertinent research in engineering and science education. Finally, we suggest directions for future research.

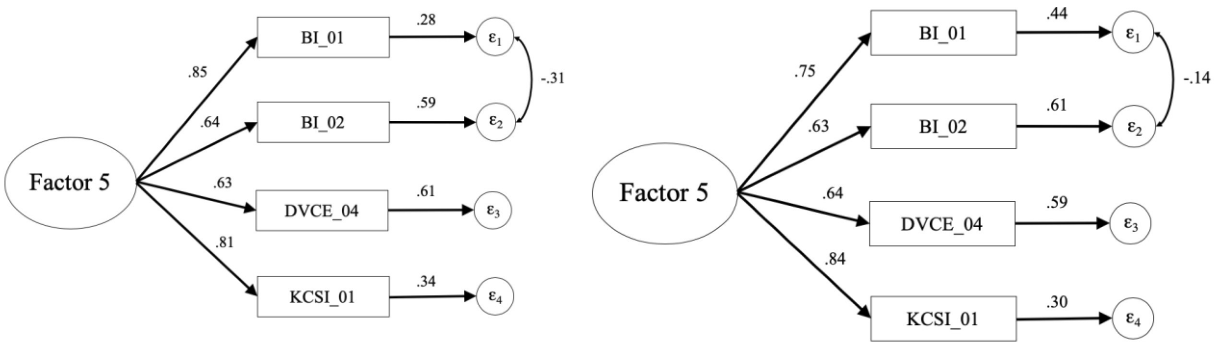

Fig. 5. CFA Models estimating Factor 5 with first-year engineering students (left) and students enrolled in engineering and science courses at a distinct university (right).

7.1 Conceptualizing the Novel Factor Structure

As a research team, we engaged with the novel factor structure via a series of conversations. The conversations began by considering potential core attributes or components of each factor. Throughout this process, we considered the alignment of this new factor structure with the original theory of the CMG designers [11] and recent validation studies [15, 16]. The following sub-sections describe each factor.

Factor 1: Valuing Community Engagement

Factor 1 included four items, each from the Dispositions domain of the CMG. More specifically, items represented two CMG subdomains: (1) Social Trustee of Knowledge and (2) Valuing Community Engagement. Taken together, these items express a personal calling, desire, or sense of duty to be of service to the betterment of the world, namely, one's community or society more broadly. As DSTK_03 states, "I believe that I have a **responsibility** to use the knowledge that I have gained to serve others." Likewise, "DVCE_02 states, "I would say that the **main purpose** of work is to improve society through my career."

The personal feeling that underlies these items does not quite capture the entirety of the essence of this factor. Rather, the items seem to indicate that one must submit oneself to these callings or felt duties and integrate such considerations into one's work, thus fulfilling one's perceived obligation to utilize one's talents and capacities to serve. One's service to society/community is also something that is "liked." In other words, one may derive pleasure, even joy, from such service. As DSTK_01 states, "I **want** to dedicate my career to improving society." Likewise, DVCE_01 states, "I **like** to be involved in addressing community issues."

Factor 2: Confidence in Building Consensus

Factor 2 included four items across two subdomains of the original CMG. Two items (DSE_02 and DSE_03) aligned with the Dispositions: Self-Efficacy sub-domain and the remaining two items (SCB_01 and SCB_02) aligned with the Skills: Consensus-Building sub-domain. Taken together, this factor assesses students' confidence in their knowledge and abilities to engage with diverse others in complex community-oriented or society-oriented issues. As DSE_02 and DSE_03 state, "I am convinced that **social problems are not too complex for me** to help solve," and "I believe that having an impact on **community problems** is **within my reach**." Core foundational beliefs in one's abilities are especially apparent in these self-efficacy items.

Interestingly, while these items involve community-oriented considerations that traditionally fall in the macro-ethics domain, the consensus-building items in particular seem to emphasize one's ability to operate successfully in the interpersonal or micro-ethics domain [see 28]. Hence, this factor potentially measures students' perceived ability to make meaningful micro-level contributions that have an impact at the macro-level. Notably, social and community designations vary across these items, which might imply variations in complexity (i.e., social problems might tend towards more complexity; community problems might tend towards more localized and potentially solvable). Thus, the construct seems to focus on the potential societal (i.e., civic) impact one can have despite variations in complexity.

Factor 3: Civic Knowledge and Skills

Factor 3 included five items, all from the Knowledge domain of the original CMG. Three items were from the Academic Knowledge subdomain (KAK_01, KAK_02, and KAK_03), whereas two items were from the Knowledge of Volunteer Opportunities sub-domain (KVO_01, KVO_03). While each item was knowledge-oriented, the items express both confidence in one's abilities to enact that knowledge in practice as well as the intention to do so. Most items were community-oriented (i.e., they explicitly used the term "community"), but one item (KAK_03) referenced society, more broadly. Thus, we feel that this Factor primarily represents localized knowledge.

Some items (not all) also explicitly connect students' disciplinary knowledge to community and societal problems. For example, KAK_02 and KAK_03 state, "I have **the professional knowledge and skills** that I need to help address community issues," and "I feel confident that I will be able to apply **what I have learned in my classes** to solve real problems in society." Thus, this factor also seems to indicate the extent to which one sees a potential connection between their specialized (i.e., disciplinary) knowledge and ways to enact that knowledge in situ.

Factor 4: Empathic Interpersonal Communication

Factor 4 represents students grappling with considerations of relationships and interpersonal encounters. All items came from the Skills domain of the original CMB Scale, but the four items spanned three sub-domains: Consensus-Building, Dispositions, and Listening. Taken together, these items represent one's confidence in engaging in interpersonal contexts, including their propensity to listen even when another's perspective differs from one's own (e.g., SL_01: "I **listen to others** and understand their perspective on controversial issues."); as well as responding to others effectively amidst disagreement (e.g., SCB_03: "When members of my group disagree on how to solve a problem, I like to try to build consensus.). This factor was notably distinct from others in that items were people-oriented rather than community or society oriented. Thus, while we recognize that effective engagement in relationships within a community are likely critical for enabling one to spark prosocial change within one's community, we recognize that these items do not explicitly call forth such considerations. We also feel that this construct is well-aligned with myriad engineering education objectives, such as teamwork, communication, and related interpersonal skills.

Factor 5: Civic Intentions and Obligations

While the previous four factors contain items from only one or two CMG domains, Factor 5 uniquely spans across more than two domains. In the CMG framework, these four items were dispersed across three domains: Behavioral Intentions, Dispositions, and Knowledge. While items Factor 5 includes items from multiple domains, a closer inspection of items reveals that, rather than describing a set of skills or knowledge, Factor 5 is organized around a specific arena of civic engagement – politics.

Factor 5 captures students' intentions and feelings of obligation towards civic engagement, namely, their intention to participate in political processes. This construct includes three primary features: (1) a sense of duty or civic obligations of political engagement (DVCE_04: "It is **important for me** to **vote** and be **politically** involved."), (2) the intention to actively participate in political processes (BI_01: "**I intend to stay current** with the local and national news," and BI_02: "**I plan to participate** in advocacy or political action groups after I graduate."), and (3) an indication of current actions that one currently partakes in to stay up-to-date with current events (KCSI_01: "**I stay up to date** on the current political issues in the community.").

7.2 Alignment with Science and Engineering Education Discourses

Thus far in this study, we did not explicitly connect these findings to science and engineering education discourses. This is partly due to the limited explicit engagement or applications of civic mindedness in engineering education. Yet, we do not claim that similar foci do not exist inside engineering and science discourses. Potential areas of connection included (1) spirituality, (2) ethics, (3) interpersonal engagement, (4) wicked problems, and (5) politics.

First, as we reviewed Factor 1, we saw potential connections to spirituality, an increasing discourse in engineering education scholarly circles [29, 30]. Specifically, the word "vocation" comes to mind when considering the fundamental ideas underlying this factor. Contemporary use of the word "vocation" may evoke images of technical occupations for which a person – properly trained through "vocational education" – is well-suited. This, however, does not quite capture the "higher calling" element arguably present within this service-oriented factor. Rather, the components of this factor hearken back to the Christian origins of the vocation concept, which stresses the idea that one is called to a particular kind of work (e.g., service) and that one can find purpose and joy in fulfilling one's obligations to love and serve others.

Moreover, in Factor 1 we see some considerations of civic virtues (e.g., awareness, responsibility, judgment, inquiry, communication, etc.) and of what it means to be a good citizen as described by Dewey [5] and Aristotle [1, 2]. It is here that we begin to see the entanglement of civics with ethics. In Factor 1, the items speak to taking responsibility for addressing larger communal issues and seeking societal betterment. Drawing on recent scholarship from Fore and Hess [31] and Nair and Bulleit [32], this is the key concern of a pragmatic Deweyian ethics, while also being profoundly relevant to the ordinary performances of technical engineering knowledge and skills. Fore and Hess [31] describe Dewey's ethics as comprising a heuristic in which "moral excellencies" (i.e., virtues) are utilized as a democratic participant inquiries into reality by developing their awareness of the moral situation, crafting informed judgments, experimenting with those judgments, and iterating on those judgments and experiments as their awareness expands. Here, we see a profound intermingling of disciplinary expertise, civic considerations, and ethical engagement.

Second, expanding upon the connections we see between civics and ethics across the constructs, we return to Factor 2, where we argue that the nature of ethics and morality in civic education are intertwined. This sentiment is shared by Ehrlich [33] who wrote, "Included in the core knowledge we consider integral to moral and civic learning is knowledge of basic ethical concepts and principles" (p. xxvi). In addition, we recognized a potential connection to the micro/macro ethics distinction that has proliferated in engineering [28]. Specifically, aspects of Factor 2 seemed to span the micro/macro divide, and thus potentially connected the two. Moreover, we posited that this factor might also correlate with students' perception to meaningful ways to have a community-impact that are not captured here, thus connecting to the engineering education discourses on social responsibility and public welfare [34].

Third, as we reviewed factors, we began to consider variations in the complexity of social issues in which students might grapple with over the course of a semester. One particular area that we considered was the emergence of a focus of wicked problems in engineering [35, 36]. Wicked problems are, by definition, not solvable [i.e., we discuss responses rather than solutions, see 37] – rather, we talk of *responses* than *solutions* to wicked problems. Hence, after participating in a course that discusses such complexities [e.g., 38], student changes could also reflect a firmer grasp of complexity rather than a reduction in self-efficacy.

Fourth, an emphasis on assessing interpersonal communication skills is one domain of interest by the National Academies [39]. We recognized that Factor 4 did not explicitly utilize the terms community or society, making it unique from other factors. Thus, while this factor did not explicitly call forth connections between interpersonal communication and community-engagement, we recognize that positive interpersonal skills align with civic-engagement skills and dispositions, such as the ability to work with diverse others [40], trust and credibility [41], and the tendency to listen [42]. Importantly, fostering interpersonal communication also requires the practice of several antecedent capacities, such as empathy [43].

Finally, the central theme of political engagement in Factor 5 calls forth considerations about the alignment between civics and politics. Morgan et al. [44] suggested that civic engagement differs from political engagement, wherein the former "tends to deal with apolitical responses to the inequitable distribution of power and capital in a society" and the latter is "much more restrictive" and "risky" (p. 109). Regardless of whether one deems Factor 5 a component of or corollary to civic engagement, we note that Factor 5 in its current state does not capture potentially important variations in how students understand the political process. The survey items reflect democratic values underlying the American political system, but students' responses may reflect their respective nationalities and cultures. For example, student's nationality may inform how they defined "local and national news" in BI_01 or their attitudes towards voting in DVCE_04. Depending on the context, the influence of nationality on responses may be an important consideration for future researchers who administer the CMG Scale.

7.3 Implications, Future Research, and Limitations

This validation study is a component of a larger investigation that seeks to transform STEM ethics instruction across curriculum towards more purposeful engagement with civic-related outcomes [anonymized for peer review]. That work theorizes that STEM programs must concern themselves with the development of civic-related skills and dispositions. Through the project, faculty learning communities are designed to foster faculty's self-efficacy in integrating community-engaged learning with ethical reflection. Thus, in that work, we theorize that community-engaged pedagogy is ideal for promoting ethical becoming [45]. That work faces its own challenges and barriers, including disciplinary norms that might make civic-engagement antithetical to the primary goals of STEM programs. Thus, this validation study will help make salient how this intervention can help reduce other troubling trends found in engineering programs [34].

In this study, we leave unexplored questions of low and high scorers, as well as whether the responses capture herein indeed represent "low" and "high" civic mindedness on associated factors. We also recognize that civic mindedness in engineering and science education might involve additional considerations that were not pronounced in the design of the original CMG Scale. For example, different views of community and stances on politics might factor into individual results. Thus, one of our next research objectives is to qualitatively explore survey respondents' perceptions of civic mindedness, thereby providing an additional validation check of this work and potential considerations for future efforts at assessing civic mindedness in higher STEM education.

There are a few noteworthy limitations of this study that warrant consideration and future study. First, ideally, the CFAs (Phase 2) would have involved no modification from the PCA (Phase 1), which was not the case here. Thus, we have concerns of Type I error, particularly on factors that required substantive modifications between Phase 1 and 2. Second, the degrees of freedom in the final factor structures tended to be low, thus presenting concerns pertaining to Type II error and statistical power [see 26]. Third, several measurement models involved correlating error terms. This issue was most problematic for Factor 5, which included a negative error term, thus suggesting this measurement model is not accounting for all variation in the dataset. Finally, Bringle et al. [15, 16] found that the CMG Scale was unidimensional. We cannot either confirm or deny this claim. Such a consideration would involve a larger sample size and nesting either all 30-items into a single factor and utilizing this factor structure and aligning it with a single factor.

8. Conclusion

In this study, we were able to achieve a structurally robust five-factor structure for the CMG Scale that we confirmed among two student samples. Following the original CMG Scale design, the authors inductively generated a four-domain structure consisting of knowledge, skills, dispositions, and behavioral dispositions. Here, the five factors had similarities to these four domains but with some slight distinctions. The five factors included (1) Valuing Community Engagement, (2) Confidence in Building Consensus, (3) Civic Knowledge and Skills, (4) Empathic Interpersonal Communication, and (5) Civic Intentions and Obligations. These constructs connected to multiple emergent domains of engineering education research, including spiritual and vocational concerns, ethics and societal issues, interpersonal skills, and political engagement. These aspects, particularly ethics and interpersonal skills, suggest a concerted focus on civics can help address aspects of program accreditation in the US. Taken together, these factors provide a means to assess civic growth among engineering students. Future validation work will include correlating factors with other prominent measures in the above-listed domains and follow-up interviews that seek to identify the alignment between these dimensions and engineering students' perceptions of community and civic engagement. In addition, we will identify pre/post changes resulting from select courses and triangulate this with qualitative data and the CMG Rubric, thus further expounding upon the impact of service learning or other community engaged experiences on students' ethical and civic development.

Acknowledgments – This material is based upon work supported by the National Science Foundation under Grant No. 1737157. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. We would also like to thank all of the students who completed the surveys associated with this study and the instructors who worked with us to collect data in their courses.

References

1. Aristotle, *Nicomachean ethics*, New York, NY: Penguin Books, 2003.
2. D. Winthrop, Aristotle and Political Responsibility, *Political Theory*, **3**(4), pp. 406–422, 1975.
3. J. A. Ramaley, The perspective of a comprehensive university, in *Civic responsibility and higher education*, T. Ehrlich Ed. Westport, CT: The American Council on Education, 2000.
4. P. M. Podsakoff, S. B. MacKenzie, R. H. Moorman and R. Fetter, Transformational leader behaviors and their effects on followers' trust in leader, satisfaction, and organizational citizenship behaviors, *The leadership quarterly*, **1**(2), pp. 107–142, 1990.
5. J. Dewey, *Democracy and education: An introduction to the philosophy of education* (Text-book series in education), New York: Macmillan, 1916, pp. xii, 434 p.
6. D. T. Hansen, Preface, in *John Dewey and our educational prospect: A critical engagmeent with Democracy and Education*, D. T. Hansen Ed. Albany, NY: State University of New York Press, 2006.
7. J. Torney-Purta, J. C. Cabrera, K. C. Roohr, O. L. Liu and J. A. Rios, Assessing civic competency and engagement in higher education: Research background, frameworks, and directions for next-generation assessment: assessing civic competency and engagement, *ETS Research Report Series*, **2015**(2), pp. 1–48, 2015.
8. J. A. Hatcher, Assessing civic knowledge and engagement, *New Directions for Institutional Research*, (149), pp. 81–92, 2011.
9. N. A. Bowman, Promoting participation in a diverse democracy: A meta-analysis of college diversity experiences and civic engagement, *Review of Educational Research*, **81**(1), pp. 29–68, 2011.
10. R. D. Reason and K. Hemer, *Civic learning and engagement: A review of the literature on civic learning, assessment, and instruments*, Washington, DC, 2015.
11. K. S. Steinberg, J. A. Hatcher and R. G. Bringle, Civic-minded graduate: A north star, *Michigan Journal of Community Service Learning*, **18**(1), pp. 19–34, 2011.

12. R. G. Bringle, M. Studer, J. Wilson, P. H. Clayton and K. S. Steinberg, Designing programs with a purpose: To promote civic engagement for life, *Journal of Academic Ethics*, **9**(2), pp. 149–164, 2011.
13. R. G. Bringle and K. S. Steinberg, Educating for informed community involvement, *American Journal of Community Psychology*, **46**(3–4), pp. 428–441, 2010.
14. S. Messick, Validity of psychological assessment: Validation of inferences from persons' responses and performances as scientific inquiry into score meaning, *American Psychologist*, **50**(9), p. 741, 1995.
15. R. G. Bringle and E. Wall, Civic-minded graduate: Additional evidence, *Michigan Journal of Community Service Learning*, **26**(1), 2020.
16. R. G. Bringle, T. W. Hahn and J. A. Hatcher, Civic-minded graduate: Additional evidence II, *Michigan Journal of Community Service Learning*, **7**(1), 2019.
17. G. R. Pike and K. Robbins, Using propensity scores to evaluate education programs, presented at the Annual meeting of the Indiana Association for Institutional Research, Indianapolis, IN, 2014.
18. B. Thompson, *Exploratory and confirmatory factor analysis: Understanding concepts and applications*, Washington DC: American Psychological Association, 2004.
19. B. G. Tabachnick and L. S. Fidell, *Using multivariate statistics*, 6th ed. Harlow: Pearson, 2014.
20. R. G. Netemeyer, W. O. Bearden and S. Sharma, *Scaling procedures: Issues and applications*. Thousand Oaks, CA: Sage Publications, 2003.
21. K. A. Douglas and Ş. Purzer, Validity: Meaning and relevancy in assessment for engineering education research, *Journal of Engineering Education*, **104**(2), pp. 108–118, 2015.
22. K. A. Douglas, A. Rynearson, S. Purzer and J. Strobel, Reliability, validity, and fairness: A content analysis of assessment development publications in major engineering education journals, *International Journal of Engineering Education*, **32**(5(A)), pp. 1960–1971, 2016.
23. J. C. Nunnally, *Psychometric theory*, New York: McGraw-Hill, 1978.
24. H. F. Kaiser, An index of factorial simplicity, *Psychometrika*, **39**(1), pp. 31–36, 1974.
25. A. B. Costello and J. W. Osborne, Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis, *Practical Assessment, Research & Evaluation*, **10**, pp. 1–9, 2005.
26. R. C. MacCallum, M. W. Browne and H. M. Sugawara, Power analysis and determination of sample size for covariance structure modeling, *Psychological Methods*, **1**(2), p. 130, 1996.
27. J. B. Schreiber, A. Nora, F. K. Stage, E. A. Barlow and J. King, Reporting structural equation modeling and confirmatory factor analysis results: A review, *The Journal of Educational Research*, **99**(6), pp. 323–338, 2006.
28. J. R. Herkert, Ways of thinking about and teaching ethical problem solving: Microethics and macroethics in engineering, *Science and Engineering Ethics*, **11**, pp. 373–385, 2005.
29. J. D. Thompson, M. Chua and C. H. Joslyn, Engineering and engineering education as spiritual vocations, presented at the ASEE Annual Conference & Exposition, Indianapolis, Indiana., 2014.
30. D. Halsmer, E. Butay, B. Hase, S. McDonough, T. Tryon and J. Weed, Exploring connections between engineering and human spirituality, presented at the ASEE Annual Conference & Exposition, Louisville, Kentucky, 2010.
31. G. A. Fore and J. L. Hess, Operationalizing Ethical Becoming as a Theoretical Framework for Teaching Engineering Design Ethics, *Science and Engineering Ethics*, pp. 1–23, 2019.
32. I. Nair and W. M. Bulleit, Pragmatism and care in engineering ethics, *Science and Engineering Ethics*, **26**(1), pp. 65–87, 2020.
33. T. Ehrlich, Preface, in *Civic responsibility and higher education*, T. Ehrlich Ed. Westport, CT: Greenwood Publishing Group, 2000.
34. E. A. Cech, Culture of disengagement in engineering education?, *Science, Technology & Human Values*, **39**(1), pp. 42–72, 2014.
35. J. Lönngren, Å. Ingerman and M. Svanström, Avoid, Control, Succumb, or Balance: Engineering Students' Approaches to a Wicked Sustainability Problem, *Research in Science Education*, journal article pp. 1–27, 2016.
36. T. Seager, E. Selinger and A. Wiek, Sustainable engineering science for resolving wicked problems, *Journal of Agricultural and Environmental Ethics*, **25**(4), pp. 467–484, 2012.
37. H. W. J. Rittel and M. M. Webber, Dilemmas in a general theory of planning, *Policy Sciences*, **4**(2), pp. 155–169, 1973.
38. J. L. Hess, S. Brownell and A. Dale, The Wicked Problems in Sustainable Engineering (WPSE) Initiative: Pilot results of a cross-institutional project-based course offering, presented at the 121st ASEE Annual Conference and Exposition, Indianapolis, IN, 2014.
39. J. Herman and M. Hilton, Eds. *Supporting students' college success: The role of assessment of intrapersonal and interpersonal competencies*, Washington, DC: The National Academies Press, 2017.
40. K. C. Adair, B. L. Fredrickson, L. Castro-Schilo, S. Kim and S. Sidberry, Present with you: Does cultivated mindfulness predict greater social connection through gains in decentering and reductions in negative emotions?, *Mindfulness*, **9**(3), pp. 737–749, 2018.
41. F. Evers and I. Berdrow, Leadership and Dependability, in *Leadership Today*: Springer, 2017, pp. 249–261.
42. J. A. Leydens and J. C. Lucena, Listening as a missing dimension in engineering education: Implications for sustainable community development efforts, *IEEE Transactions on Professional Communication*, **52**(4), pp. 359-376, 2009.
43. J. L. Hess, A. Chase, G. A. Fore and B. Sorge, Quantifying interpersonal tendencies of engineering and science students: A validation study, *International Journal of Engineering Education*, **34**(6), pp. 1754–1767, 2018.
44. D. L. Morgan, K. B. Davis and N. López, Engineering political fluency: Identifying tensions in the political identity development of engineering majors, *Journal of Engineering Education*, **109**(1), pp. 107–124, 2020.
45. G. A. Fore, J. L. Hess, B. Sorge, M. F. Price, M. A. Colean, T. W. Hahn and J. A. Hatcher, An introduction to the Integrated Community-Engaged Learning and Ethical Reflection Framework (I-CELER). *Paper presented at the American Society for Engineering Education*, Salt Lake City, UT., 2018.

Appendix A: Civic Minded Graduate Scale Items

#	Item	Description
1	KVO_01	I know a lot about opportunities to become involved in the community.
2	KAK_01	I am able to plan or help implement an initiative that improves the community.
3	SD_01	I appreciate how my community is enriched by having some cultural or ethnic diversity.
4	KAK_02	I have the professional knowledge and skills that I need to help address community issues.
5	BI_01	I intend to stay current with the local and national news.
6	SCB_01	I have often been able to persuade others to agree with my point of view.
7	KVO_02	I am very familiar with clubs and organizations that encourage and support community involvement for college students.
8	SL_01	I listen to others and understand their perspective on controversial issues.
9	DSE_01	I can contribute to improving life in my community.
10	KAK_03	I feel confident that I will be able to apply what I have learned in my classes to solve real problems in society.
11	DSTK_01	I want to dedicate my career to improving society.
12	DVCE_01	I like to be involved in addressing community issues.
13	KCSI_01	I stay up to date on the current political issues in the community.
14	DVCE_02	I would say that the main purpose of work is to improve society through my career.
15	KVO_03	I would say that most other students know less about community organizations and volunteer opportunities than I do.
16	SL_02	I am a good listener, even when peoples' opinions are different from mine.
17	BI_02	I plan to participate in advocacy or political action groups after I graduate.
18	SD_02	I am able to respond to others with empathy, regardless of their backgrounds.
19	BI_03	I intend to be involved in volunteer service after I graduate.
20	DSTK_02	I feel a deep conviction in my career goals to achieve purposes that are beyond my own self-interest.
21	KCSI_02	I am prepared to write a letter to the newspaper or community leaders about a community issue.
22	KCSI_03	I am aware of a number of community issues that need to be addressed.
23	DSE_02	I am convinced that social problems are not too complex for me to help solve.
24	SCB_02	Other students who know me well would describe me as a person who can discuss controversial social issues with civility and respect.
25	DSTK_03	I believe that I have a responsibility to use the knowledge that I have gained to serve others.
26	DVCE_03	I have a sense of who I am, which includes a sincere desire to be of service to others.
27	DSE_03	I believe that having an impact on community problems is within my reach.
28	SCB_03	When members of my group disagree on how to solve a problem, I like to try to build consensus.
29	SD_03	I prefer to work in settings in which I interact with people who are different from me.
30	DVCE_04	It is important for me to vote and be politically involved.

Appendix B: Cronbach's Alpha Across Data Sets

Cronbach's Alpha Statistics for Original Civic-Minded Graduate Scale Constructs

Construct	# of items	PCA	CFA 1	CFA2
KVO: Knowledge – Volunteer Opportunities	3	0.67*	0.73	0.75
KAK: Knowledge – Academic Knowledge and Technical Skills	3	0.70	0.78	0.67*
KCSI: Knowledge – Contemporary Social Issues	3	0.73	0.75	0.77
SL: Skills – Listening	2	0.79	0.76	0.68*
SD: Skills – Diversity	3	0.62*	0.67*	0.73
SCB: Skills – Consensus-Building	3	0.63*	0.70	0.65*
DVCE: Dispositions – Valuing Community-Engagement	4	0.70	0.77	0.73
DSE: Dispositions – Self-Efficacy	3	0.70	0.72	0.69*
DSTK: Dispositions – Social Trustee of Knowledge	3	0.78	0.83	0.84
BI: Behavioral Intentions	3	0.65*	0.64	0.66*

* Indicates That Cronbach's alpha is below 0.70, the sought threshold (see DeVellis, 2011).

Cronbach's Alpha for Refined Constructs

		University 1		University 2
Construct	**# of items**	**PCA**	**CFA**	**CFA**
Factor 1: Service as a Vocation or Calling	4	0.84	0.89	0.87
Factor 2: Confidence in Building Consensus	4	0.73	0.73	0.73
Factor 3: Civic Knowledge and Skills	5	0.78	0.83	0.77
Factor 4: Empathic Interpersonal Communication	4	0.81	0.82	0.74
Factor 5: Civic Intentions and Obligations	4	0.81	0.80	0.80

Appendix C: Civic-Minded Graduate Scale Items and Descriptive Statistics by Phase

Item	Item Description	Phase 1 (n = 434)		Phase 2 Part 1		Phase 2 Part 3	
		M	*SD*	*M*	*SD*	*M*	*SD*
KVO_01	I know a lot about opportunities to become involved in the community.	5.80	1.68	6.11	1.74	6.13	2.00
KAK_01	I am able to plan or help implement an initiative that improves the community.	5.30	1.80	5.96	1.78	5.86	2.04
SD_01	I appreciate how my community is enriched by having some cultural or ethnic diversity.	7.09	1.65	7.08	1.60	6.91	1.96
KAK_02	I have the professional knowledge and skills that I need to help address community issues.	5.54	1.93	6.35	1.61	6.20	1.83
BI_01	I intend to stay current with the local and national news.	6.36	1.97	6.56	1.87	6.49	1.99
SCB_01	I have often been able to persuade others to agree with my point of view.	6.32	1.58	6.72	1.49	6.44	1.68
KVO_02	I am very familiar with clubs and organizations that encourage and support community involvement for college students.	5.61	1.83	6.03	1.84	6.12	2.03
SL_01	I listen to others and understand their perspective on controversial issues.	7.40	1.35	7.43	1.30	7.27	1.45
DSE_01	I can contribute to improving life in my community.	6.87	1.52	6.91	1.38	6.96	1.61
KAK_03	I feel confident that I will be able to apply what I have learned in my classes to solve real problems in society.	6.86	1.71	6.76	1.65	6.90	1.65
DSTK_01	I want to dedicate my career to improving society.	7.02	1.78	6.98	1.70	7.11	1.92
DVCE_01	I like to be involved in addressing community issues.	6.44	1.78	6.58	1.63	6.48	1.92
KCSI_01	I stay up to date on the current political issues in the community.	5.62	2.15	5.89	2.06	5.84	2.27
DVCE_02	I would say that the main purpose of work is to improve society through my career.	6.38	1.86	6.67	1.76	6.63	1.94
KVO_03	I would say that most other students know less about community organizations and volunteer opportunities than I do.	4.43	1.74	5.04	1.83	5.00	2.12
SL_02	I am a good listener, even when peoples' opinions are different from mine.	7.46	1.45	7.52	1.44	7.43	1.47
BI_02	I plan to participate in advocacy or political action groups after I graduate.	4.44	2.26	5.05	2.19	5.32	2.36
SD_02	I am able to respond to others with empathy, regardless of their backgrounds.	7.32	1.52	7.46	1.37	7.34	1.70
BI_03	I intend to be involved in volunteer service after I graduate.	6.34	2.03	6.52	1.86	6.79	2.04
DSTK_02	I feel a deep conviction in my career goals to achieve purposes that are beyond my own self-interest.	6.70	1.84	6.84	1.67	7.18	1.74
KCSI_02	I am prepared to write a letter to the newspaper or community leaders about a community issue.	4.52	2.26	4.95	2.18	5.17	2.49
KCSI_03	I am aware of a number of community issues that need to be addressed.	5.01	2.01	5.79	1.97	5.82	2.13
DSE_02	I am convinced that social problems are not too complex for me to help solve.	5.61	1.88	6.12	1.75	5.90	2.00
SCB_02	Other students who know me well would describe me as a person who can discuss controversial social issues with civility and respect.	6.61	1.75	6.80	1.70	6.67	1.81
DSTK_03	I believe that I have a responsibility to use the knowledge that I have gained to serve others.	6.73	1.73	6.84	1.65	6.84	1.88
DVCE_03	I have a sense of who I am, which includes a sincere desire to be of service to others.	6.59	1.75	6.77	1.74	6.90	1.86
DSE_03	I believe that having an impact on community problems is within my reach.	6.56	1.62	6.76	1.50	6.47	1.74
SCB_03	When members of my group disagree on how to solve a problem, I like to try to build consensus.	7.04	1.43	7.26	1.35	6.74	1.65
SD_03	I prefer to work in settings in which I interact with people who are different from me.	6.35	1.76	6.80	1.55	6.31	1.96
DVCE_04	It is important for me to vote and be politically involved.	6.60	2.21	6.73	2.02	6.60	2.14

Appendix D: Inter-item Correlations for PCA (n = 402; outliers were removed)

#	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	KVO_01	1																													
2	KAK_01	0.54	1																												
3	SD_01	0.32	0.30	1																											
4	KAK_02	0.47	0.59	0.30	1																										
5	BI_01	0.26	0.16	0.18	0.27	1																									
6	SCB_01	0.24	0.32	0.21	0.45	0.32	1																								
7	KVO_02	0.52	0.35	0.34	0.41	0.28	0.35	1																							
8	SL_01	0.30	0.24	0.39	0.35	0.22	0.33	0.38	1																						
9	DSE_01	0.41	0.47	0.35	0.41	0.28	0.33	0.39	0.46	1																					
10	KAK_03	0.38	0.33	0.40	0.32	0.31	0.28	0.35	0.39	0.50	1																				
11	DSTK_01	0.31	0.31	0.29	0.28	0.29	0.25	0.32	0.35	0.38	0.40	1																			
12	DVCE_01	0.36	0.42	0.29	0.39	0.37	0.27	0.32	0.36	0.49	0.41	0.70	1																		
13	KCSI_01	0.22	0.22	0.10	0.29	0.70	0.25	0.28	0.16	0.21	0.22	0.28	0.46	1																	
14	DVCE_02	0.29	0.27	0.27	0.28	0.26	0.22	0.36	0.30	0.25	0.26	0.68	0.54	0.32	1																
15	KVO_03	0.37	0.39	0.13	0.35	0.25	0.25	0.33	0.15	0.29	0.21	0.29	0.39	0.36	0.31	1															
16	SL_02	0.27	0.16	0.37	0.25	0.20	0.25	0.27	0.64	0.34	0.32	0.31	0.29	0.16	0.29	0.12	1														
17	BI_02	0.18	0.27	0.11	0.26	0.45	0.23	0.26	0.15	0.24	0.18	0.26	0.39	0.55	0.24	0.36	0.13	1													
18	SD_02	0.18	0.19	0.38	0.23	0.19	0.21	0.29	0.46	0.38	0.25	0.35	0.34	0.19	0.25	0.15	0.52	0.22	1												
19	BI_03	0.24	0.30	0.25	0.21	0.26	0.17	0.26	0.22	0.40	0.24	0.35	0.45	0.27	0.29	0.33	0.26	0.40	0.34	1											
20	DSTK_02	0.34	0.29	0.29	0.32	0.27	0.26	0.38	0.31	0.42	0.32	0.53	0.45	0.29	0.53	0.32	0.30	0.33	0.38	0.50	1										
21	KCSI_02	0.19	0.29	0.13	0.35	0.39	0.28	0.22	0.10	0.27	0.13	0.32	0.42	0.42	0.30	0.37	0.08	0.52	0.18	0.37	0.38	1									
22	KCSI_03	0.32	0.35	0.16	0.41	0.40	0.31	0.28	0.12	0.28	0.22	0.28	0.42	0.49	0.30	0.41	0.10	0.40	0.23	0.27	0.26	0.52	1								
23	DSE_02	0.14	0.27	0.19	0.27	0.36	0.36	0.21	0.23	0.37	0.28	0.31	0.35	0.32	0.31	0.28	0.20	0.38	0.31	0.28	0.34	0.40	0.37	1							
24	SCB_02	0.10	0.13	0.24	0.28	0.35	0.36	0.28	0.42	0.28	0.25	0.27	0.34	0.34	0.34	0.21	0.37	0.32	0.42	0.31	0.29	0.33	0.25	0.39	1						
25	DSTK_03	0.23	0.29	0.27	0.32	0.30	0.30	0.27	0.26	0.34	0.30	0.52	0.53	0.33	0.54	0.28	0.26	0.29	0.37	0.44	0.50	0.31	0.33	0.38	0.46	1					
26	DVCE_03	0.35	0.30	0.39	0.40	0.26	0.32	0.37	0.38	0.41	0.37	0.53	0.53	0.25	0.45	0.31	0.35	0.24	0.40	0.45	0.54	0.28	0.27	0.32	0.38	0.62	1				
27	DSE_03	0.23	0.35	0.29	0.33	0.25	0.32	0.30	0.30	0.46	0.36	0.39	0.50	0.29	0.38	0.28	0.31	0.31	0.37	0.41	0.45	0.35	0.34	0.53	0.38	0.49	0.52	1			
28	SCB_03	0.25	0.22	0.32	0.30	0.23	0.37	0.37	0.42	0.38	0.33	0.34	0.31	0.17	0.33	0.16	0.44	0.17	0.43	0.29	0.37	0.23	0.20	0.36	0.40	0.38	0.47	0.50	1		
29	SD_03	0.28	0.30	0.37	0.30	0.29	0.25	0.33	0.33	0.34	0.31	0.39	0.43	0.30	0.38	0.23	0.33	0.36	0.38	0.37	0.36	0.31	0.29	0.34	0.33	0.39	0.44	0.40	0.42	1	
30	DVCE_04	0.10	0.03	0.17	0.14	0.45	0.13	0.20	0.21	0.14	0.11	0.23	0.32	0.50	0.31	0.20	0.20	0.47	0.24	0.30	0.34	0.27	0.22	0.28	0.30	0.30	0.21	0.31	0.21	0.29	1

Appendix E: Principal Components (eigenvectors) in Unrotated Solution

#	Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Unexplained
1	KVO_01	0.16	–0.10	0.40	0.02	0.26	31%
2	KAK_01	0.17	–0.03	0.43	–0.04	–0.10	34%
3	SD_01	0.15	–0.25	0.02	0.08	0.14	57%
4	KAK_02	0.19	–0.03	0.34	0.13	–0.11	39%
5	BI_01	0.17	0.27	–0.07	0.28	0.26	32%
6	SCB_01	0.16	–0.02	0.11	0.27	–0.28	51%
7	KVO_02	0.18	–0.09	0.19	0.12	0.19	51%
8	SL_01	0.17	–0.30	–0.09	0.26	0.15	33%
9	DSE_01	0.20	–0.15	0.15	0.05	–0.08	47%
10	KAK_03	0.17	–0.17	0.12	0.07	0.13	57%
11	DSTK_01	0.21	–0.05	–0.06	–0.37	0.17	30%
12	DVCE_01	0.23	0.05	0.02	–0.24	0.11	34%
13	KCSI_01	0.17	0.36	–0.05	0.18	0.26	25%
14	DVCE_02	0.20	0.01	–0.09	–0.34	0.18	38%
15	KVO_03	0.16	0.17	0.24	–0.08	–0.01	56%
16	SL_02	0.16	–0.29	–0.19	0.22	0.15	37%
17	BI_02	0.17	0.34	–0.06	0.12	0.05	40%
18	SD_02	0.17	–0.19	–0.23	0.12	–0.05	48%
19	BI_03	0.18	0.05	–0.08	–0.18	–0.05	58%
20	DSTK_02	0.21	–0.02	–0.07	–0.26	0.05	43%
21	KCSI_02	0.17	0.31	0.04	–0.01	–0.21	42%
22	KCSI_03	0.17	0.26	0.18	0.06	–0.12	45%
23	DSE_02	0.18	0.12	–0.10	0.09	–0.39	42%
24	SCB_02	0.18	0.00	–0.26	0.20	–0.17	45%
25	DSTK_03	0.21	0.01	–0.15	–0.27	–0.12	38%
26	DVCE_03	0.22	–0.13	–0.06	–0.21	–0.08	38%
27	DSE_03	0.21	–0.02	–0.09	–0.07	–0.32	40%
28	SCB_03	0.18	–0.20	–0.15	0.11	–0.21	44%
29	SD_03	0.19	–0.03	–0.09	0.00	0.01	60%
30	DVCE_04	0.14	0.23	–0.29	0.11	0.29	40%

Justin L. Hess is an assistant professor in the School of Engineering Education at Purdue University. Dr. Hess received each of his degrees from Purdue University, including a PhD in Engineering Education, a Master of Science in Civil Engineering, and a Bachelor of Science in Civil Engineering. His primary research interests focus on several interrelated spaces: empathy; engineering ethics; diversity, equity, and inclusion; design; and innovation. He is currently the division chair-elect of the Liberal Education/Engineering & Society Division (LEES) of ASEE.

Athena Lin is a graduate student in the School of Engineering Education at Purdue University and an NSF Graduate Research Fellow. She received her BS in Materials Science and Engineering from the University of Illinois at Urbana-Champaign. Her research interests center around engineering ethics and diversity, equity, and inclusion. Through her work, she seeks to advance dialogue about engineering as a moral profession.

Grant A. Fore is a research associate in the STEM Education Innovation and Research Institute at IUPUI. Mr. Fore is also a PhD candidate in anthropology at the University of Cape Town in Cape Town, South Africa. His research is primarily focused on the teaching and learning of ethics through experiential pedagogies, specifically within the contexts of engineering design and the ecological/environmental sciences. Through his scholarship, Mr. Fore hopes to promote learning opportunities for post-secondary students that take seriously alternative ways of being and doing that value the ethical becoming of humans and the things they co-create through a commitment to relationality, interconnectivity, indebtedness, beauty, care, reflection, and inquiry.

Tom Hahn is the Director of Research and Program Evaluation in the Center for Service & Learning at IUPUI. He has a bachelor's degree in political science and a graduate degree in public administration from Old Dominion University. Tom worked for 17 years in planning, assessment, and program development at Eastern Virginia Medical School. His current responsibilities include conducting research on service learning and civic engagement, disseminating high-quality scholarship through research briefs and publications, planning, and implementing Research Academy activities, and writing grants to secure external funding (primarily for research).

Brandon Sorge is an Assistant Professor of STEM Education Research in the Department of Technology Leadership and Communication at the Purdue School of Engineering and Technology at IUPUI. His research interests include all aspects of STEM education, especially the impacts of policy on the development of a STEM literate workforce. He also conducts research related to leadership and the role of corporate responsibility in employee recruitment and retention. Before coming to IUPUI, Brandon ran the day-to-day operations of the Indiana STEM Resource Network where he co-founded the Indiana Science Initiative, which provides research-based science materials and professional development to approximately 2200 teachers and over 50,000 students each year.