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An Exploratory Study on the Contextual Challenges and Barriers of Introducing Sustainability to First Year Engineering Students

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Abstract

Sustainability has become increasingly significant for the engineering profession with reference made to it in a variety of professional engineering standards. Sustainability, while not enough at times, requires both engineers and citizens, to consider the breadth and depth the impact of our own lives in tandem with the products and services engineers design globally. The success in integrating novel sustainability concepts in existing curricula relies upon three main components of an individual's context: perceptions, awareness and knowledge. To effectively convey those concepts, Faculty needs to become aware of the current state, including potential barriers and enablers, present in the first year students' context. Given the baseline identified through an initial effort of curricula redesign, Faculty needs to engage in a reinforcing process where one or several of these three components are sequentially and/or concurrently impacted.

In general, individuals, and first year students in particular, function in very distinctive contexts. They achieve a level of awareness regarding a concept based on a continuous exchange of information within their contexts. Moreover, they perceive a concept through the happening (or not happening) of contextual events and they acquire knowledge either by choice or by need. The challenge of curricula redesign relies upon the infusion of knowledge that should be aligned with the individual's context: perception and awareness. This alignment occurs through several interactions between those three components.

Initial experiences with sustainability education engaging students through demonstration of both local and global impacts of their behavior, partnered with the use of social media, are important to enhance students' positive perception toward sustainability. Moreover, this engagement also increases the students' willingness to incorporate sustainability into their future courses, particularly when solving real design problems in their workplace. The additional sustainability module enables first-year engineering students at both universities to understand the concept of sustainability and its relationship with the engineering design process as it is applied to solve real-world problems.

Justification

All engineers should be familiar with the concept of sustainability. ABET (ABET website at http://abet.org/DisplayTemplates/DocsHandbook.aspx?id=3149 visited on January 3, 2014) has listed sustainability as one of the constraints for engineering designs under general criterion 3 student outcome item c. The Engineer of 2020 report presented by the National Academy of Engineering,) has noted as well the importance of sustainability as one of the opportunities and challenges for the engineer of 2020 NAE (NAE website at http://www.nae.edu/File.aspx?id=10368 visited on January 3, 2014. In a study, Allen et al.

(2008)[1] attempted to benchmark sustainable engineering education through a survey aimed at engineering department heads. In this survey, with more than 270 respondents, about 80% reported teaching sustainable engineering-focused courses or the integration of sustainable engineering material into existing courses. Increased attention to teaching engineering students about sustainability, sustainable development, and sustainable design is also evident on the basis of the number of papers presented at the American Society for Engineering Education (ASEE) annual conference that included these keywords in their titles, which increased from 1 to 3 papers in the 1998–2002 period to 27 papers in 2009 to 36 in 2012 and 52 in 2013.

Additionally, the Code of Ethics for the National Society of Professional Engineers (NSPE) states that engineers have an ethical obligation to hold paramount the health, safety and welfare of the public in the performance of their professional duties (NSPE website at www. http://www.nspe.org/Ethics/CodeofEthics/index.html visited on January 3, 2014). The Code also addresses sustainability: “Engineers shall strive to adhere to the principles of sustainable development in order to protect the environment for future generations” in the section about Professional Obligations (NSPE website at http://www.nspe.org/Ethics/CodeofEthics/index.html visited on January 3, 2014). But how do we include the concepts of public service and sustainability into engineering education?

Many universities have available courses mainly focused on sustainability, with 64 civil/architectural/environmental engineering courses identified in a recent benchmarking survey by Allen et al.[1]. These courses are most often electives targeted to upper-division students, such as the Green Engineering and Sustainability course at Michigan Technological University and Yale University referenced by Zhang et al.[2] and the seminar course at Lamar University mentioned by Koehn et al.[3]. An alternative approach to teaching sustainability in upper-level elective courses is to introduce sustainability at the beginning of the curriculum, during the first and second-year courses. The expectation is that introducing sustainability to first-year students will reinforce the knowledge that all engineers need to consider sustainability on all their design projects.

At the two universities involved in this exploratory study, first-year engineering students are preparing themselves for the future by understanding sustainability and incorporating it into their overall design process. Through a Department of Education funded grant, our university has initiated a long-term effort to incorporate education of sustainability, and its related professional standards and accreditations, into engineering courses. Initially, freshman engineering students from our university were partnered with one large private university in South America to be introduced to the sustainability concept through the completion of an additional module that was part of their required Introduction to Engineering course.

Curricular Context

At our university, the Introduction to Engineering is a required two-credit hours, first-year course for all students pursuing a major on engineering at our university. This course meets for 50 minutes twice a week over the 15 weeks of the semester. This course not only presents the students with study skills in engineering, the engineering profession, the engineering design process, and ethics in engineering but also motivates the students to learn about current issues such as sustainability. Therefore, one of the most important outcomes of this course is to encourage students to understand the challenges when designing product and services while considering sustainability into their designs.

At the large private university in South America, the Introduction to Industrial Engineering is a required one-credit hour, first-year course for all students pursuing a major on industrial engineering. The course meets for 60 minutes once a week over the 16 weeks of the semester. In addition to the topics presented in the Introduction to Engineering course, this course describes the administrative process in the large private university and asks the students to develop and present a business plan for a potential start-up company in manufacturing or service at the end of the semester where sustainability is used to measure the viability of such potential company.

Both universities are interested in incorporating sustainability into their engineering programs. The collaboration presented in this paper is a first attempt to evaluate the context's effects on engineering students' knowledge and perception on sustainability. Both universities are planning to incorporate sustainability into junior and senior courses as well as the creation of a major on sustainable systems engineering open to all engineering disciplines.

Sustainability Module

During the fall semester of 2013, freshman engineering students from our university were partnered with one large private university in South America to be introduced to the sustainability concept through the completion of an additional module that was part of their required Introduction to Engineering course in our university (one section with 19 students) and Introduction to Industrial Engineering course in our partner university (two sections, one with 39 students and the other with 26 students). These traditional courses include study skills in engineering, the engineering profession, the engineering design process, and ethics in engineering among others. This additional module was offered through a virtual classroom, via Skype, with a live, active twitter feed as a supporting tool for both students and faculty. The module was presented in two languages, English and Spanish, at the large private university in South America.

For the group in our university, a sustainability module encompassing one lecture in the course, one written homework assignment worth 3% of the total course grade, and a design project presentation in class were required. The module introduced a range of topics, including definitions of sustainability, the triple bottom line definition according to scientists and economists, the Impact, Population, Affluence, Technology also known as the IPAT equation used to measure the environmental impact of human activities, the unique challenges of international sustainable development, the limits of growth, the concept of carrying capacity, and ecological footprint analysis. As mentioned in the curricular context section, students at the large private university developed and presented a business plan for a potential start-up company in manufacturing or service where sustainability is used as one of the measures of viability of such a potential company. Table 1 presents all the topics and educational materials used in the sustainability module added to all the groups.

Table 1. Topics and educational materials used in the added sustainability module

Topic	**Educational Material**
Introduction to Sustainability	Presentations and discussions
Triple bottom Line	Presentations and discussions
The IPAT equation	Presentations and discussions
Limits of growth and the concept of carrying capacity	Presentations and discussions
Assessing the foot print	Presentations, discussions, and homework assignments
Introducing sustainability into the design process	Students' presentations
Evaluating the foot print	Posters
Developing and evaluating a new manufacturing or service company by using sustainability	Final project and students' presentations

Evaluation of Sustainability Awareness, Perception, and Knowledge

The challenge in curricula redesign relies upon the infusion of knowledge that must be aligned with the individual's perception and awareness of her/his context. This alignment can only be achieved through a continuous feedback process correlating those three components: knowledge, perception and awareness. To establish the baseline of understanding of sustainability, a 9 questions assessment survey was used to measure students' self rated perception, knowledge and awareness regarding sustainability. The survey is presented in Appendix 1a. This exploratory study analyzed a modified version of the instrument (Appendix 1b) used by Bielefeldt (2010)[4] - who developed it by compiling questions from previous studies (see Bielefeldt, 2010, p. 4)[4], to investigate if it can be used to validate the proposed components and their suggested structural relation.

Table 2 presents the proposed components; their conceptual definitions; their operationalization through the chosen questions from the existing instrument, and the rationale for this categorization when infusing sustainability in first-year engineering curricula. The data illustrates the foundation from which student knowledge, perception and awareness was questioned thus resulting in a designed approach intended to advance the student's results.

Table 2. The three components analyzed in the added sustainability module

Component	Knowledge	Awareness	Perception
Adopted definition	The range of information, understanding and awareness regarding a formal concept.	"Understanding of the activity of others, which provides a context for your own activity." Dourish & Bellotti[6]	"[Level of processing] organization, identification, and interpretation of sensory information [that entails awareness and the creation of a mental representation]." Schacter et al, 2009[5]
Questions [Instrument]	1[4] 2[4] 3[4]	4[4] 5[4] 6[4]	7[4] 8[4] 9[4] 10[4] 11[4] 12[4] 13* 14*
Rationale	Information regarding sustainability is provided to students through two different teaching techniques: lectures (at both universities) and a project –experiential learning (at the large private university in South America). Understanding and awareness may change (or not) as learning progresses.	Sustainability awareness relates to both: the individual's perception of sustainability within a context and a contextual aspect that facilitates that perception.	Perception of sustainability is the ability of one to experience or see sustainability in their surrounding environment. This includes being exposed to properties, elements and stimuli that relate to sustainability such as physical and natural environmental factors, economic realities, and social involvement.

* These questions were developed by the Sustainability Education Specialist at our university.

This study is the exploratory phase of a long term effort to be carried out by the large private university in South America and our university. In this phase, a modified instrument was used to analyze the suggested components and their structural relationship. Principal factor extraction with oblimin rotation was performed through SPSS® for a sample of 63 observations taken during the summer semester 2013. Principal components extraction was used to estimate the number of factors, absence of multicollinearity and factorability of the correlation matrices.

SPSS® provided a configuration of 6 factors when the latent root criterion (eigenvalues greater than 1 considered significant) was used. When inspecting the measure of sampling adequacy (MSA), not all the measures in the anti-image matrix were greater than 0.5 showing that not all the items were relevant. The MSA values for each variable were evaluated and variables with the lowest MSA were first deleted until all variables achieved an acceptable MSA value. The Kaiser-Meyer-Olkin (KMO) measure was 0.774 indicating that the correlations are large enough to conduct factor analysis.

Three factors were finally extracted. All factors were internally consistent and well defined by the variables. Communality values as shown in Table 3 tended to be significant. Variables p5, p6, p7, p8, p9, a1 and a4 corresponding respectively to questions in the survey failed to load on any factor. Only oblique rotation was requested given that the factors are theorized to be correlated. Loadings of variables on factors, communalities, percent of variance and covariance are shown in Table 3. Interpretative labels for each factor are shown in the footnote.

Table 3. Factors loadings, communalities (h2) and percent of variance for principal factors extraction and oblimin rotation

Item	**F1***	**F2**	**F3**	**h2**
p1	-0.804			0.709
p2	-0.765			0.631
p3	-0.82			0.678
p4	-0.746			0.581
a2		0.897		0.806
a3		0.894		0.804
k1			0.905	0.824
k2			0.944	0.892
k3			0.894	0.833
Percent of Variance	41.544	17.759	15.789	

*F1: Perception, F2: Awareness, F3: Knowledge

For more detail in the analysis, please see Appendix 2. This preliminary phase was found to be an important stage to recognize the need to tailor an instrument for the future phases of this study. In order to validate these results, this study will move forward to a confirmatory analysis during the spring semester 2014 with an appropriate sample size of 100 or larger. During the fall semester 2013 only 13 data points were collected.

Results

First year engineering students at both universities took the existing survey, which was available, online, before and after the module was completed. At our university, the response rate was 68% (13 out 19 students responded both the pre and post-survey) and at the large private university in South America, the response rate was 71% (46 out 65 students responded both the pre and post-survey). By analyzing the results of the pre-survey for students at both universities, we can conclude that their level of knowledge, perception and awareness was not statistically different. For the knowledge component, knowing the three pillars of the definition of sustainability, students at both universities were at the same level (Student's t test with 57 degrees of freedom assuming equal variance and a p-value = 0.648) as shown in Figure 1.

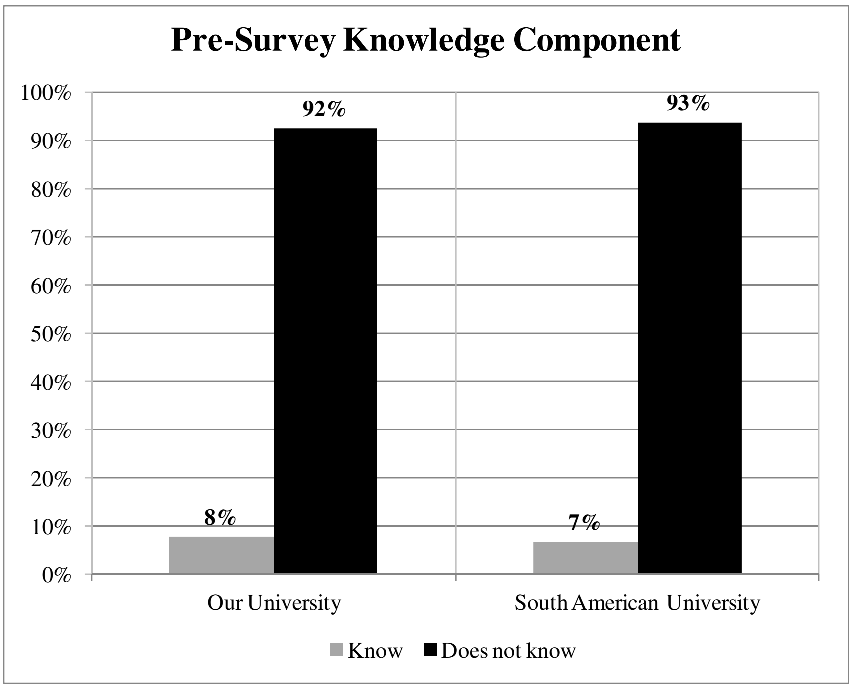

Figure 1. Results of the questions regarding the knowledge component in the pre-survey

For the perception component, students at both universities were at the same level on the 5 questions used (Student's t test with 57 degrees of freedom assuming equal variance and p-values ranging from 0.120 to 0.996). For the awareness component, students at both universities were at the same level on the 3 questions used (Student's t test with 57 degrees of freedom assuming equal variance and p-values ranging from 0.134 to 0.714).

Comparison of knowledge, perception and awareness for both universities before and after the added sustainability module

Based on the results of the post-survey, it can be concluded that in general students' knowledge, perception, and awareness levels at the large private university in South America were changed after their exposure to the added sustainability module. For the knowledge component there was a statistically representative increase in the number of students knowing the three pillars of the definition of sustainability (Student's t test paired with 45 degrees of freedom and a p-value less than 0.05). On the other hand, at our university, the increase in knowledge was not statistically representative (Student's t test paired with 12 degrees of freedom and a p-value = 0.165) as shown in Figure 2.

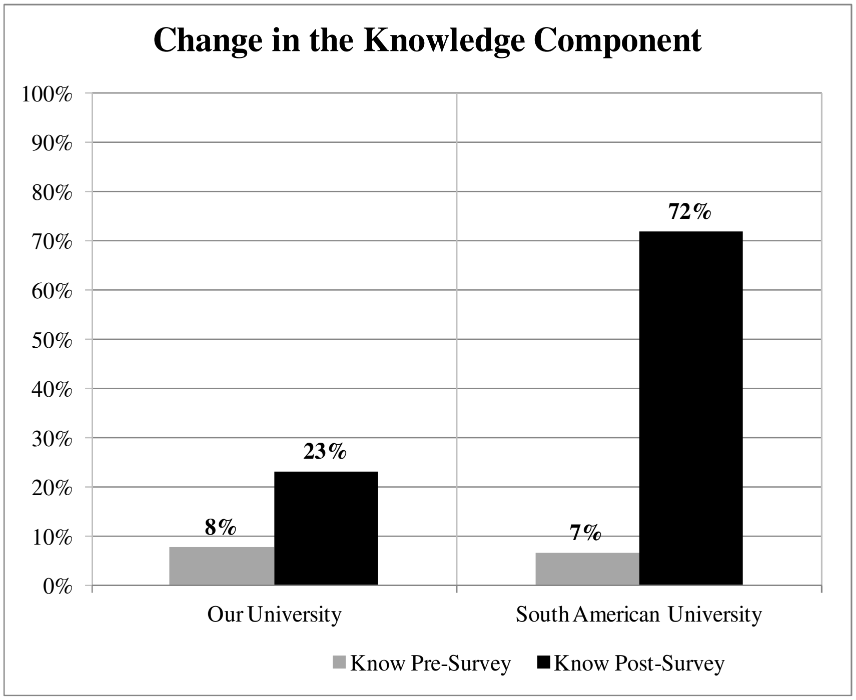

Figure 2. Results of the questions regarding the knowledge component in the pre and post-survey

Similar results were found for the five questions regarding the perception component. For the large private university in South America there was a statistically representative increase in the number of students changing their perceptions about sustainability as described by questions 1, 3 and 4 (Student's t test paired with 45 degrees of freedom and p-values all less than 0.05). For questions 2 and 5, there was not statistically change. On the other hand, at our university, the change in perception was not statistically representative as described by all the five questions (Student's t test paired with 12 degrees of freedom and all p-values greater than 0.05).

Finally, the results of the three questions regarding the awareness component are similar to the perception component. For the large private university in South America there was a statistically representative increase in the students' level of awareness about sustainability as described by questions 1 and 2 (Student's t test paired with 45 degrees of freedom and p-values all less than 0.05). For question 3, there was not statistically increase. On the other hand, at our university, the increase in awareness about sustainability was not statistically representative as described by all the three questions (Student's t test paired with 12 degrees of freedom and all p-values greater than 0.05).

A preliminary explanation for such a difference could be the group projects that students at the large private university in South America did. These projects consisted of developing a business plan for a potential start-up company including sustainability, as defined by the three pillars (People, Profit, Planet), as one of the measures of the potential company viability. We think this project is one of the main factors responsible for the increase in students' knowledge, perception, and awareness at the private large university in South America.

Conclusions

First-year engineering students are receptive and responsive to the addition of topics such as sustainability into their courses whenever instructors are successful in showing them the importance and relevance in today's engineering profession. Initial experiences with sustainability are important to increase students' positive attitude toward sustainability and to increase their willingness to incorporate this concept into their future courses and when dealing with real design problems in their workplace.

The additional sustainability module helped first-year engineering students understand the concept of sustainability and its relationship with the engineering design process as it is applied to solve real-world problems. The students at the large private university showed an increase in their knowledge and positive perception about sustainability.

The final course project developed by the students at the large private university might be an important factor explaining their substantial increase in knowledge, awareness and positive perception about sustainability.

In the short term, the sustainability module is being improved and incorporated into the spring sessions and the survey is being validated by using additional data points. In the medium term, two to three years from now, the plan is to offer a minor in sustainability available for all the undergraduate students at our university. At the large private university in South America, a sustainability course is being developed to be offered to freshman and sophomore engineering students. Finally, a major on sustainable systems engineering is in the long term plan at our university, five to seven years from now. Sustainable systems engineering is the application of engineering knowledge to help organizations select and implement cost effective strategies for sustainability including: energy systems, use of water and other natural resources, conservation, recycling, transportation, life cycle product and process design, and human health and safety. A sustainable systems engineer (1) performs audits in organization or communities and recommends cost effective strategies for sustainability, (2) locates, hires, and supervises specialists who can implement the strategies recommended in 1, and (3) designs and implements processes to monitor and maintain and to continually improve and update the strategies implemented in 2.

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Bibliography

1. Allen, D., et al. (2008). "Benchmarking sustainable engineering education: Final report." Grant X3-83235101-0, U.S. Environmental Protection Agency, Washington, DC.
2. Zhang, Q., Zimmerman, J., Mihelcic, J., and Vanasupa, L. (2008). "Civil and environmental engineering education (CEEE) transformational change: Tools and strategies for sustainability integration and assessment in engineering education." Proc. ASEE Annual Conf. and Exposition, American Society for Engineering Education, Washington, DC.
3. Koehn, E., Patel, D., and Khonde, S. (2009). "Introduction of sustainability to civil and construction engineering students." Proc. ASEE Annual Conf. and Exposition, American Society for Engineering Education, Washington, DC.
4. Bielefeldt, A.R. 2010. "Evolution of a Sustainability Focused First-Year Environmental Engineering Course." American Society for Engineering Education (ASEE) Annual Conference and Exposition Proceedings. (Paper 2010-353). Environmental Division. June 20-23, Louisville, KY.
5. Dourish, P. and Bellotti, V. (1992). Awareness and Coordination in Shared Workspaces. Proceedings of the ACM Conference on Computer-Supported Cooperative Work CSCW'92(Toronto, Ontario), 107-114. New York: ACM.
6. Schacter, D.L., Gilbert, D.T., & Wagner, D.M. (2009). Psychology. New York: Worth.

Appendix 1a. Survey taken by students at both universities.

#	Questions					
1.	What is the first pillar of Sustainability?					
2.	What is the second pillar of Sustainability?					
3.	What is the third pillar of Sustainability?					
		Yes	Unsure	No		
4.	Have you previously taken a formal course which addressed sustainability or sustainable development?					
5.	Have you previously been involved in an out-of-school sustainability related activity?					
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
6.	Sustainability is a key component of (environmental) engineering					
7.	Sustainability is a key component of all STEM disciplines					
8.	Sustainable development is a good thing					
9.	I am a passionate advocate of sustainability					

Appendix 1b. Modified survey.

#	Questions					
1.	What is the first pillar of Sustainability?					
2.	What is the second pillar of Sustainability?					
3.	What is the third pillar of Sustainability?					
		Yes	Unsure	No		
4.	Have you previously taken a formal course which addressed sustainability or sustainable development?					
5.	Have you previously been involved in an out-of-school sustainability related activity?					
		Not familiar at all	Slightly familiar	Somewhat familiar	Moderately familiar	Extremely familiar
6.	Rate your personal level of familiarity with the term Sustainability.					
		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
7.	Sustainability is a key component of (environmental) engineering					
8.	Sustainability is a key component of all STEM disciplines					
9.	Sustainable development is a good thing					
10.	I am a passionate advocate of sustainability					
11.	Studying sustainability is a waste of time					
12.	The earth has plenty of natural resources for future generations					
13.	Technological progress will overcome all ecological problems we face and eliminate extreme poverty within my lifetime					
14.	Rate how severe you think problems related to global climate change will be	Minimal	Mild	Moderate	Strong	Severe
15.	What do you believe is the most severe environmental problem facing the planet?	Depletion of Natural Resources	Water Issues	Climate Change	Loss of Habitat	Air Pollution

Appendix 2. Exploratory Factor Analysis.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.774
Bartlett's Test of Sphericity	Approx. Chi-Square	297.648
	Df	55
	Sig.	.000

Anti-image Matrices

		k1	k2	k3	a2	a3	p1	p2	p3	p4	p5	a1
Anti-image Covariance	k1	.331	-.120	-.074	.123	-.077	.015	-.042	-.007	.071	.024	-.016
	k2	-.120	.229	-.137	.004	-.016	.060	-.077	.005	-.030	-.028	.008
	k3	-.074	-.137	.256	-.091	.030	-.010	.086	.001	.006	-.009	.042
	a2	.123	.004	-.091	.498	-.304	.047	-.098	-.038	.026	.016	.102
	a3	-.077	-.016	.030	-.304	.517	-.097	.135	.021	.050	.095	.034
	p1	.015	.060	-.010	.047	-.097	.464	-.121	-.181	-.142	.000	.036
	p2	-.042	-.077	.086	-.098	.135	-.121	.639	-.117	-.077	.026	-.023
	p3	-.007	.005	.001	-.038	.021	-.181	-.117	.514	-.048	.099	-.103
	p4	.071	-.030	.006	.026	.050	-.142	-.077	-.048	.569	.142	-.028
	p5	.024	-.028	-.009	.016	.095	.000	.026	.099	.142	.667	.168
	a1	-.016	.008	.042	.102	.034	.036	-.023	-.103	-.028	.168	.684
Anti-image Correlation	k1	.792[a]	-.434	-.255	.304	-.185	.039	-.091	-.016	.164	.052	-.034
	k2	-.434	.762[a]	-.567	.011	-.047	.183	-.201	.014	-.084	-.073	.020
	k3	-.255	-.567	.798[a]	-.254	.082	-.028	.213	.002	.015	-.022	.101
	a2	.304	.011	-.254	.511[a]	-.600	.098	-.173	-.074	.048	.028	.174
	a3	-.185	-.047	.082	-.600	.560[a]	-.197	.236	.042	.091	.161	.057
	p1	.039	.183	-.028	.098	-.197	.819[a]	-.222	-.370	-.276	.000	.064
	p2	-.091	-.201	.213	-.173	.236	-.222	.742[a]	-.203	-.127	.041	-.036
	p3	-.016	.014	.002	-.074	.042	-.370	-.203	.851[a]	-.089	.169	-.174
	p4	.164	-.084	.015	.048	.091	-.276	-.127	-.089	.875[a]	.230	-.044
	p5	.052	-.073	-.022	.028	.161	.000	.041	.169	.230	.837[a]	.249
	a1	-.034	.020	.101	.174	.057	.064	-.036	-.174	-.044	.249	.867[a]

a. Measures of Sampling Adequacy(MSA)

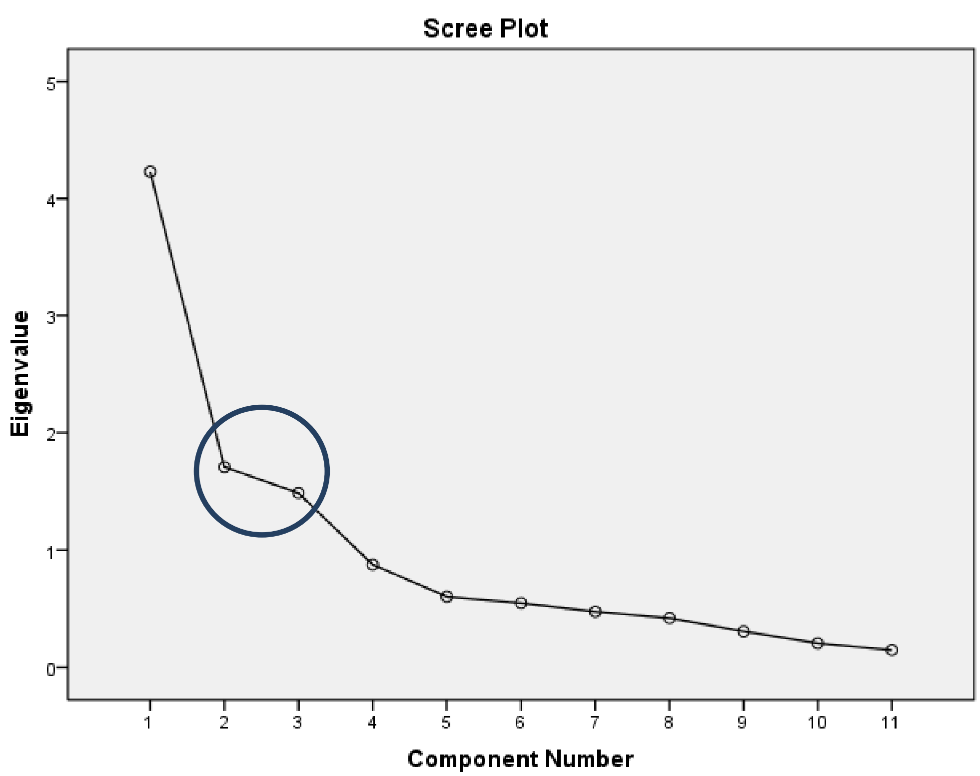
When inspecting the MSA, all measures in the anti-image matrix were greater than 0.5 indicating that the data has the structure to apply factor analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.229	38.449	38.449	4.229	38.449	38.449	3.436
2	1.709	15.537	53.986	1.709	15.537	53.986	1.988
3	1.486	13.511	67.496	1.486	13.511	67.496	3.206
4	.875	7.953	75.449				
5	.602	5.472	80.921				
6	.548	4.979	85.900				
7	.475	4.314	90.215				
8	.419	3.813	94.028				
9	.306	2.781	96.809				
10	.205	1.863	98.672				
11	.146	1.328	100.000				

Extraction Method: Principal Component Analysis.
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

The measure of common variance extracted from data (lambda = 7.424 >1) and the cumulative variation (67.496% > 60%) are considered appropriate.



The scree test showed the cutoff point between 3 and 4 factors given that after 4 factors the curve begin to straighten. The first factor extracted the highest percentage of common variance.

When conducting the rotation, 3 factors where extracted. The loadings for each variable are as follows:

Structure Matrix

	Component		
	1	2	3
k1	.310	.078	.908
k2	.351	.188	.944
k3	.422	.315	.892
a2	.100	.888	.131
a3	.119	.874	.197
p1	-.762	-.011	-.474
p2	-.698	-.192	-.090
p3	-.814	-.079	-.314
p4	-.739	-.194	-.385
p5	.670	-.029	.275
a1	-.538	-.462	-.290

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Pattern Matrix[a]

	Component		
	1	2	3
k1	-.018	-.066	.925
k2	.002	.039	.936
k3	.091	.169	.832
a2	-.040	.894	.003
a3	-.044	.869	.075
p1	-.694	.135	-.241
p2	-.756	-.107	.203
p3	-.813	.051	-.024
p4	-.682	-.068	-.125
p5	.673	-.141	.051
a1	-.455	-.381	-.063

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Given the sample size of 63, factor loadings of +/- 0.70 or higher are needed for practical significance (based on a 0.05 significance level, a power level of 80 percent); however, for interpretation purposes of the structure, factor loadings greater than or equal to 0.50 were included.

When assessing communalities, p5 and a1 did not meet acceptable levels of explanation. Based on the factor loadings and some communalities less than 0.5, a re-specification of the factor model is proposed by deleting a1 and p5 one by one.

Communalities

	Initial	Extraction
k1	1.000	.829
k2	1.000	.892
k3	1.000	.834
a2	1.000	.790
a3	1.000	.769
p1	1.000	.642
p2	1.000	.530
p3	1.000	.666
p4	1.000	.565
p5	1.000	.469
a1	1.000	.439

Extraction Method: Principal Component Analysis.

Final results are presented as follows:

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.738
Bartlett's Test of Sphericity	Approx. Chi-Square	259.193
	df	36
	Sig.	.000

Anti-image Matrices

		k1	k2	k3	a2	a3	p1	p2	p3	p4
Anti-image Covariance	k1	.333	-.119	-.074	.131	-.082	.017	-.044	-.016	.068
	k2	-.119	.230	-.142	.002	-.013	.059	-.076	.013	-.024
	k3	-.074	-.142	.260	-.102	.032	-.013	.090	.012	.013
	a2	.131	.002	-.102	.514	-.326	.043	-.097	-.023	.035
	a3	-.082	-.013	.032	-.326	.531	-.100	.136	.010	.033
	p1	.017	.059	-.013	.043	-.100	.466	-.120	-.189	-.149
	p2	-.044	-.076	.090	-.097	.136	-.120	.642	-.138	-.092
	p3	-.016	.013	.012	-.023	.010	-.189	-.138	.558	-.095
	p4	.068	-.024	.013	.035	.033	-.149	-.092	-.095	.608
Anti-image Correlation	k1	.782[a]	-.431	-.250	.316	-.196	.043	-.096	-.037	.152
	k2	-.431	.746[a]	-.579	.007	-.037	.181	-.198	.037	-.065
	k3	-.250	-.579	.773[a]	-.279	.085	-.036	.221	.032	.033
	a2	.316	.007	-.279	.462[a]	-.625	.089	-.169	-.043	.063
	a3	-.196	-.037	.085	-.625	.535[a]	-.201	.233	.019	.059
	p1	.043	.181	-.036	.089	-.201	.799[a]	-.220	-.371	-.279
	p2	-.096	-.198	.221	-.169	.233	-.220	.698[a]	-.230	-.146
	p3	-.037	.037	.032	-.043	.019	-.371	-.230	.833[a]	-.163
	p4	.152	-.065	.033	.063	.059	-.279	-.146	-.163	.874[a]

a. Measures of Sampling Adequacy(MSA)

When inspecting the MSA, a2 measure in the anti-image matrix was not greater than 0.5. However, conceptually, this variable is important to be included in the study. It is expected to improve MSA measures in future research when the analysis includes more data points.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.739	41.544	41.544	3.739	41.544	41.544	2.860
2	1.598	17.759	59.303	1.598	17.759	59.303	1.795
3	1.421	15.789	75.092	1.421	15.789	75.092	3.056
4	.598	6.647	81.739				
5	.531	5.901	87.639				
6	.421	4.678	92.318				
7	.339	3.772	96.089				
8	.205	2.282	98.371				
9	.147	1.629	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

The measure of common variance extracted from data (lambda = 6.758 >1) and the cumulative variation (75.092% > 60%) are considered appropriate.

Communalities

	Initial	Extraction
k1	1.000	.824
k2	1.000	.892
k3	1.000	.833
a2	1.000	.806
a3	1.000	.804
p1	1.000	.709
p2	1.000	.631
p3	1.000	.678
p4	1.000	.581

Extraction Method: Principal Component Analysis.

Pattern Matrix[a]

	Component		
	1	2	3
k1	-.002	-.066	.916
k2	-.007	.036	.941
k3	.086	.160	.840
a2	-.025	.899	.012
a3	.025	.882	.057
p1	-.740	.140	-.237
p2	-.827	-.102	.215
p3	-.813	.075	-.046
p4	-.688	-.075	-.138

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 8 iterations.

Structure Matrix

	Component		
	1	2	3
k1	.310	.070	.905
k2	.327	.174	.944
k3	.401	.296	.894
a2	.098	.897	.136
a3	.162	.894	.197
p1	-.804	.007	-.476
p2	-.765	-.179	-.089
p3	-.820	-.040	-.320
p4	-.746	-.186	-.389

Pattern Matrix[a]

	Component		
	1	2	3
k1	-.002	-.066	.916
k2	-.007	.036	.941
k3	.086	.160	.840
a2	-.025	.899	.012
a3	.025	.882	.057
p1	-.740	.140	-.237
p2	-.827	-.102	.215
p3	-.813	.075	-.046
p4	-.688	-.075	-.138

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Factor loadings and communalities meet guidelines for statistical significance and acceptable levels of explanation respectively.