Measuring Students' Motivation to Engage in Sustainable Engineering Practice

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Abstract – *Worldwide, political and professional organizations consider engineering to be a key profession in the application of sustainable development to solve global problems. In order for engineering professionals to play a key role in sustainable development, they must be motivated to engage in such practice. The purpose of this study is to develop a measure of students' motivation to engage in sustainable engineering practice. A survey instrument was developed by applying a mixed-method approach consisting of a survey instrument design phase, small pilot study, and national study.*

The proposed survey instrument includes 3 open-ended and 40 closed-ended questions to measure previous experiences and stereotypes, self-concept of abilities, and subjective task value with respect to sustainable engineering practice. Factor analyses of the closed-ended questions resulted in the identification of 7 factors, 5 of which can be considered to be strong factors. Evidence for validity and reliability is established through the pilot study and factor analyses.

Keywords: Sustainable engineering practice; motivation theory; survey instrument development.

1. INTRODUCTION

In 2015 the United Nations outlined 17 Sustainable Development Goals (SDGs), of which a minimum of 11 relate directly to the engineering profession [20]. In educational research, the accepted definition of sustainable development (SD) is: "Development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs" [21]. Additionally, SD is considered to have three central pillars: social, environmental, and economic, as well as a holistic element that incorporates each of the three pillars. As outlined by the UNESCO Engineering Initiative and numerous engineering organizations worldwide, engineering is considered to be a key profession in the achievement of the United Nations SDGs [7,19,22].

In response to the changes in the roles of engineering professionals with regards to SD, Engineering Education for Sustainable Development (EESD) has emerged with an aim to teach engineering students to think critically and to

act for SD. EESD research is often dominated by topics regarding inhibitors to change in engineering institutions and single case initiatives to embed SD topics in engineering courses [3]. However, some literature explores students' approaches towards sustainable engineering (SE) as opposed to SD [11,14]. This change in terminology signifies an increase in the depth of consideration of SD in engineering education (EE). This study aims to further increase that depth by considering sustainable engineering practice (SEP) within the context of the professional engineering practice.

This study hinges on the notion that in order for practicing professional engineers to contribute significantly to the achievement of the SDGs, they must be engaged in SEP. To engage in SEP, they must be motivated to do so. However, the motivation of professional engineers and engineering students for engaging in SEP is largely unknown. As part of a larger study on exploring students' motivation to engage in SEP this paper considers the specific research question as follows: How can undergraduate students' motivation to engage in sustainable engineering practice be measured using a survey instrument?

2. LITERATURE REVIEW

Literature was reviewed on various approaches of measuring SD in the context of EE. There were three distinct approaches to measurement: (a) inclusion of SE topics in institutions and program assessments; (b) students' knowledge, attitudes, perception, and competency with respect to SD and SE; and (c) students' motivation for SE. Overall, the reviewed literature highlighted the complexity of SD in general and in the context of EE as well as the importance of context.

2.1. Inclusion of Sustainable Engineering Topics in Institutions and Programs

Allen, Allenby, Bridges, Crittenden, Davidson, Hendrickson, Matthew, Murphy and Pijawka reported findings of a project commissioned by the US Environmental Protection Agency that examined SE at accredited engineering institutions across America. Allen

et al. gathered data using two questionnaires and interviews. A questionnaire aiming to determine the prevalence of SE at the departmental level was sent to 1368 administrative heads of engineering departments and yielded a 20% response rate. The second questionnaire, which gathered information on SE courses and research programs, was sent to 327 individuals identified as SE champions and yielded a 43% response rate [1]. The response rates indicate nationwide interest in SE and enhance the credibility of the study. However, the researchers indicated one concern for reliability: the questionnaires “did not provide a comprehensive definition of either ‘sustainability’ or ‘sustainable engineering,’ which reflects the state of the art, but necessarily increases the subjectivity inherent in these results” [1].

Hanning, Abellsson, Lundqvist, and Svanström compared engineering students’ competences in the environment and SD with the needs of Swedish industries. In the context of courses, the researchers equated competences to learning outcomes. The amount of environmental and SD content in 70 courses offered at Chalmers University of Technology was assessed using a five level scale [12]. To support the analysis, two questionnaires were distributed: one to third year engineering students and one to engineering alumni. The student questionnaire studied the student perception of SD learning and what they thought they may lack while the alumni questionnaire studied the alumni perception of necessary SD competences and what competences they may lack. The researchers suggested that to further such research, assessment tools are needed to evaluate the quality and level of competences in SD among students.

2.2. Students’ Knowledge, Attitudes, Perception, and Competency

Three distinct approaches were discovered in measuring students’ knowledge, attitudes, perception, and competency with regards to SD in the context of EE: (a) knowledge-based questionnaires; (b) concept maps on SD; and (c) rubrics to assess application of SE principle.

2.2.1 Knowledge-Based Questionnaires. One of the most notable studies regarding measurement of SD in the context of EE was conducted by Adisa, Azapagic, Perdan, and Shallcross. The researchers conducted what they believed to be the first international survey of engineering students’ knowledge of SD. Adisa, Azapagic, Perdan, and Shallcross devised and distributed a questionnaire to 40 universities in Europe, North and South America, the Far East, and Australia, which yielded 3134 responses from 21 of the contacted universities. The questionnaire was comprised of three parts: (a) demographic information and previous SD experiences; (b) knowledge and understanding of SD and environmental stewardship; and (c) SD interest. Part b asked students to indicate their level

of understanding of 45 concepts on a four-point scale with labels not heard of, heard of but could not explain, have some knowledge, and know a lot. The concepts focused primarily on the environmental pillar of SD. Part c of the questionnaire asked students to rank the importance of various aspects of SD. From an instrument development perspective, limited discussion was provided on the validity and reliability of the questionnaire. However, the questionnaire has been used by other researchers for assessing students’ knowledge of SD [17].

2.2.2 Sustainable Development Concept Maps. Concept maps have been used as an alternative approach to measuring students’ knowledge and comprehension of SD. Lourdel, Grondran, Laforest, Debray, and Brodhag used concept maps created by students on the topic of SD as a data source for analysis. Based on the work of Legrand in 2000, Lourdel et al. proposed a method of analysis using six semantic categories. The semantic categories contained the three pillars of SD as well as multidimensional approaches of the SD, procedural and political approaches, and actors and stakeholders [13].

Segalàs, Ferrer-Balas and Mulder also used concept maps to evaluate improvements in students’ knowledge of SD after taking one of six SD courses offered at three European engineering institutions. Participants completed concept maps on SD prior to and after taking one of the six SD courses. Segalàs et al. used ten different categories than Lourdel et al. to complete a quantitative analysis of the concept maps: (a) environmental; (b) resource scarcity; (c) social impact; (d) values; (e) future generations (temporal); (f) unbalances (spatial); (g) technology; (h) economy; (i) education; and (j) actors and stakeholders [18]. In both studies, the quantitative analysis considered the categories defined and the connectivity among them to determine values for the category relevance and a complexity indicator. These studies highlighted the ability of concept maps to capture the complexity of SD in a manner that may be difficult with traditional survey instruments.

2.2.3 Rubric-Based Assessment of Sustainable Engineering Principles. McCormick et al. developed and tested a rubric to assess students’ ability to apply sustainability principles in engineering design and problem solving challenge questions. The rubric incorporated analytic and holistic elements to assess elements of students’ ability on a 6-point scale. The analytic rubric included three elements with respect to SD pillars: (a) concepts (1 point); (b) crosslinks (2 points); and (c) interdependency (3 points). The concepts and crosslinks elements each had one subsection per SE aspect, whereas interdependency had one section. The holistic portion of the rubric included three elements: (a) interpret problems or issues; (b) analyze/evaluate ideas or solutions; and (c) structure and explain problem solutions, and self-regulate ability to solve problem [15].

The rubric was tested by asking students to answer one of two challenge questions set in different contexts. The first question was in the context of a college campus and the second question was in the context of a low income community in Tanzania, but no information was provided on the development of the challenge questions. The majority of the students answered the challenge question in the context of the low income Tanzanian community. Because the study was conducted at American universities and the context of the question was in a developing country it is possible that the question was biased towards the social and economic elements of SD. This highlights the importance of context when measuring SD and SE.

The researchers assessed the reliability of the rubric after a fourth iteration on three sets of challenge question responses. Three forms of reliability were assessed: (a) Inter-rater reliability using Cohen's kappa (0.89); (b) intra-rater reliability using Cronbach's alpha (0.91); and (c) parallel reliability using Pearson's product moment correlation coefficient (0.75) [14]. Each of the three forms of reliability were found to be acceptable. The researchers also discussed construct validity of the rubric and identified an assessment of criterion validity as a next step.

2.3. Measurement to Assess Students' Motivation for Sustainable Engineering

McCormick et al. developed a survey consisting of 32 statement-based questions to assess students' motivation to engage in SE. Items were adopted from existing surveys to represent three motivational constructs: (a) self-efficacy (13 items): students' beliefs about their own abilities; (b) value (7 items): students' beliefs about task importance, intrinsic motivation and extrinsic motivation; and (c) affect (8 items): students' internal reaction to the task. These motivational constructs were developed from Eccles et al.'s expectancy value theory of motivation. In the survey, 4 of the 32 questions were negatively phrased. The survey was pilot tested in 2010 and 2011 at three American universities and a total of 515 responses were received.

The researchers conducted an exploratory factor analysis and obtained three factors. The internal consistency of each factor was assessed using Cronbach's alpha coefficients with values of 0.96, 0.79, and 0.87 for the self-efficacy, value, and affect factors, respectively [14]. Despite having good internal consistency (Cronbach's alpha greater than 0.70 [8]), the survey items could be improved to remove bias and a 7-point Likert-type scale could be implemented to increase variance in responses. Many of the SE value items were highly saturated [14]. Limited information was provided on content validity of the items. This study is of significant importance to the current research on developing a survey instrument to measure students' motivation to engage in SEP.

3. CONCEPTUAL FRAMEWORK

The study conducted by McCormick et al. used a simplification of the Eccles et al. expectancy-value theory of achievement-related choices. In this model, choices are assumed to be influenced by negative and positive task characteristics. In the context of SEP there are three options from which students may choose: (a) to actively engage in SEP; (b) to inactively engage in SEP; and (c) to not engage in SEP. The key determinants of choice are relative value and expectation of success of the various options [6]. Relative value and expectation of success are influenced by social cognitive variables, which in turn are influenced by the individual's perceptions of other people's attitudes and expectations of the individual, and by the individual's perception of previous achievement outcomes. In the model, expectancies are defined as "individual's beliefs about how well they will do on upcoming tasks, either in the immediate or long term future" [6]. Subjective task value is defined by four components as shown in Table 1.

Table 1: Components of subjective task value [6]

Component	Description
Attainment Value	The personal importance of doing well on the task, and the relevance of engaging in the task for confirming or disconfirming aspects of one's self-schema.
Intrinsic Value	The enjoyment the individual gets from engaging in a task and/or the subjective interest the individual has for the task.
Utility Value	Determined by how well a task relates to the individual's future goals, e.g. career goals.
Relative Cost	The negative aspects of engaging in the task, for instance the fear of failure or success, the amount of effort needed to engage in the task, and the lost opportunities that result from making one choice rather than another.

For this study, the expectancy for success when engaging in SEP was simplified and represented by two constructs with respect to SEP: (a) stereotypes and previous experiences; and (b) self-concept of abilities. The four value components were used as constructs representing subjective task value. For students, these constructs were considered to be manifested in academic, disciplinary, and professional engineering or industry contexts. Active engagement in SEP entails the practice of engineering in accordance with SE principles [9], as outlined by Gagnon, Leduc, and Savard, and the use of the SE design process, as outlined by Gagnon, Leduc, and Savard [9,10]. The SE principles are based on the Triple Bottom Line (TBL) elements that correspond to the central pillars of SD.

4. INITIAL SURVEY INSTRUMENT DESIGN

The initial survey instrument was developed from McCormick et al.'s instrument with significant modifications and additions to include all elements of the conceptual framework. The initial survey instrument was comprised of demographic questions, 3 open-ended questions and 62 closed-ended questions to measure the expectancy-value theory elements as follows: (a) stereotypes and previous experiences (20 items); (b) self-concept of abilities (14 items); and (c) subjective task value (28 items).

The questions for the stereotypes and previous experiences element included the 3 open-ended questions (SD and SEP definitions and common SE considerations) and closed-end for the importance of the central pillars and holistic element of SD, disciplinary stereotypes, academic experiences, and professional engineering and industry stereotypes. The questions for the self-concept of abilities element were 7-point confidence level questions pertaining to the central pillars and holistic element of SD and elements of the SE design process. The subjective task value questions included questions on the four elements in Table 1 as follows: (a) 13 closed-end for attainment value using SE principles; (b) 5 closed-end for intrinsic value in the professional engineering and industry context; (c) 4 closed-end for utility value in the professional engineering and industry context; and (d) 6 closed-end for relative cost related to both the academic and the professional engineering and industry contexts. All items for the stereotypes and previous experiences and subjective task value elements used a 7-point Likert-type scale to increase the variance in responses and effectively decrease Hawthorne and experimenter effects.

5. PILOT STUDY

A pilot study of the initial survey instrument was conducted prior to the national distribution of the survey. The purposes of the pilot study were to reduce measurement error and to provide evidence to evaluate the performance of the survey questions. A mixed-method convergent parallel design was used where quantitative data was collected in the form of survey responses and qualitative data was collected in the form of think-aloud interviews.

The task-focused model of measurement error includes four components: (a) comprehension problems; (b) validity problems; (c) processing difficulties; and (d) pronunciation or communication difficulties [4]. The think-aloud interviews addressed all but the pronunciation or communication components of measurement error. Pretesting of survey instruments can provide three types of evidence to evaluate the performance of survey questions: (a) statistical; (b) direct study of the question-and-answer

process; and (c) experimental [4]. The survey responses provided statistical evidence and the think-aloud interviews provided direct study of the question-and-answer process.

5.1. Sampling Design

Graduate engineering students at Queen's University were selected by convenience sampling to be recruited for the pilot study. Undergraduate students were not considered as they were recruited in the large scale study. The survey was distributed electronically to all graduate engineering students. At the end of the survey, participants were asked if they would like to participate in a think-aloud interview. Purposeful sampling was used to select participants from a range of engineering disciplines for think-aloud interviews.

5.2. Think-Aloud Interviews

Cognitive interviews allow for the direct study of the question-and-answer process for survey questions [4]. The two techniques in cognitive interviewing are the think-aloud protocol and probing. In think-aloud interviews, the participant is asked "to 'think-aloud' as he or she answers the questions or completes the questionnaire" [4]. The think-aloud is driven by the participant, whereas probing is driven by the interviewer. However, the two methods can be combined in a single interview. In this study, the think-aloud interviews used a semi-structured format to incorporate the think-aloud protocol and comprehension probing questions. The interview protocol included an introduction to the study, an explanation of the think-aloud method, and an example of the think-aloud process for a survey question. Participants were provided with a copy of the survey questions and were asked to explain their thought process for answering each survey question. Depending on the response, comprehension probing questions were used to gain further understanding of the participants' thought process. The interviews were a maximum of 75 minutes in duration.

5.3. Modifications to the Survey Instrument

A total of 14 survey responses were collected and 4 think-aloud interviews were conducted. The transcripts of the think-aloud interviews were analyzed on a question-by-questions basis and by deductive coding using the task-focused model of measurement error outlined by Collins.

There were three main themes from the deductive coding analysis: (a) importance of context; (b) simplicity in terminology; and (c) simplicity in phrasing. Some questions did not explicitly state the context (academic or real-world), which resulted in variations in interpretations by the think-aloud participants. In some cases, the

variations impacted participants' responses. There was some confusion with respect to terminology commonly used in SD and in engineering design. There was additional confusion as a result of the phrasing of some questions, primarily those that were determined to have more than one interpretation.

By addressing the three themes, modifications were made to the survey instrument to reduce the number of questions and to improve reliability and validity. Modifications to specific questions primarily used the question-by-question think-aloud interview analysis while the descriptive statistics were occasionally used as additional support.

6. NATIONAL STUDY

The national study used an Ex-Post Facto research design. Such research designs allow for the exploration of a potentially causal relationship among variables where the independent variable cannot be controlled by the researcher [16]. The purpose of this study was to provide statistical evidence to evaluate the performance of survey.

6.1. Sampling Design

A combination of cluster and convenience sampling was used to select 8 institutions across Canada. Factors considered when selecting the institutions included geographic location, institution size, and variety of engineering programs. Students at the participating institutions received electronic invitations to complete the survey via email from faculty members, departments, and other institutional organizations, newsletters, and institutional websites. Responses were collected electronically using FluidSurvey. A total of 243 completed responses were collected from students across all years of study in 19 different disciplines of engineering. The sample was comprised of 62.6% males and 37.4% females, which includes significantly more females than the Canadian engineering student population ratio as of 2015 ($t = 5.608$, $p < .001$).

6.2. Survey Instrument Design

The updated survey instrument included 3 open-ended questions and 44 closed-ended questions distributed among the expectancy-value theory elements as follows: (a) 3 open-ended and 13 closed-ended for stereotypes and previous experiences; (b) 14 closed-ended for self-concept of abilities; and (c) 17 closed-ended for subjective task value. All closed-ended questions used 7-point Likert-type scales. The attainment value component of the subjective task value element was removed due to complexity and overlap with the intrinsic value component. The subjective task value questions were distributed among the

components as follows: (a) 8 closed-ended for intrinsic value; (b) 4 closed-ended for utility value; and (c) 5 closed-ended for relative cost.

7. RESULTS AND ANALYSIS

Only the closed-ended questions were considered in the analysis presented. Three exploratory factor analyses were conducted, with one analysis per expectancy-value theory element. Bartlett's Test of Sphericity was found to be significant for all analyses. The maximum likelihood method of extraction and direct oblimin method of rotation were used for all analyses. The maximum likelihood method has been shown to be superior to other extraction methods when factors are underextracted or factors are correlated with unequal loadings [23]. Factors were extracted by considering the point of inflection on the Scree plot, which likely resulted in underextraction. All pattern and structure matrices obtained from the analyses indicated unequal factor loadings. The direct oblimin method is an oblique method of rotation, which assumes that factors are correlated. This assumption was confirmed, as all factors within each analysis were found to be correlated.

A total of 7 factors were extracted as a result of the three factor analyses and 40 of the 44 survey questions were used. For each analysis, the number of factors to retain and survey questions to include were determined using a combination of the Scree plots, factor eigenvalues, and the pattern and structure matrices. Factors with loading from fewer than 3 survey questions were removed as recommended by Costello and Osborne. The ultimate goal of an exploratory factor analysis is to obtain simple structure in the pattern matrix. Simple structure occurs when there is no crossloading among the factors [5]. Unfortunately, the structure matrices exhibited complex structure. However, only cases of double loading were observed and in the majority of these cases, the loading on one factor was substantially higher than on the other. Factors with 5 or more strongly loading questions (.50 or greater) are considered strong factors [5]. To simplify the analysis, the pattern matrices were interpreted for naming factors, and loadings less than 0.31 were suppressed [5]. There was no crossloading in the pattern matrices.

7.1. Stereotypes and Previous Experiences

The first factor analysis was conducted on the stereotypes and previous experiences element of the expectancy-value theory. The analysis included 12 survey questions that resulted in 3 factors accounting for 42.9% of variance. The KMO Measure of Sampling Accuracy value was found to be 0.83, which is above the recommended minimum value of 0.60 [8]. The question "Sustainability is currently a shared vision among all engineers working in a single company" was removed as it did not load to any

factors in the pattern or structure matrix. Each factor had 4 loading questions as shown in Table 2. The Academic factor has 3 strongly loading questions, whereas the Application of SEP and Engineering Discipline factors only have 2 strongly loading questions.

The stereotypes and previous experiences element was expected to be manifested in academic, disciplinary, and professional engineering or industry contexts. The first factor corresponds to the academic context and the third factor to the disciplinary context. However, the second factor, Application of SEP, corresponds to both contexts. The structure matrix had double loadings for nearly all survey questions loading to the Academic and Engineering Discipline factors. The correlation between these factors was -0.54, which suggests that students associate academic experiences and disciplinary stereotypes.

Table 2: Pattern matrix for the stereotypes and previous experiences element

Survey Question	Academic	App. Of SEP	Eng. Discipline
Number of Courses with SEP	0.44		
Sustainable engineering practice is valued by my course instructors.	0.63		
I am expected to apply sustainable engineering practice in my design projects.	0.93		
I receive marks in my courses for creating sustainable engineering solutions.	0.82		
I have to create opportunities myself to apply sustainable engineering practice in my design projects.		0.62	
Course projects in my discipline have limited sustainability considerations.		0.35	
I could have applied sustainable engineering practice more in my design projects.		0.45	
Practicing engineers should apply sustainable engineering practice to more elements of their projects.		0.60	
Sustainable engineering practice is easily applied to real-world projects in my discipline.			-0.52
Other engineering disciplines have more sustainability considerations than my discipline.			0.39
Sustainable engineering practice is deeply integrated into my discipline.			-0.69
Sustainability is just a word used in industry for promotion and public image.			0.34

The Cronbach's alpha values were found to be 0.81, 0.55, and 0.60 for the Academic, Application of SEP, and Engineering Discipline factors, respectively. Cronbach's alpha is a reliability estimate that measures the internal consistency among items in a scale with an acceptable minimum of 0.70 [8]. Considering the reliability estimates and the number of strong loading questions, only the Academic factor can be considered to be acceptable.

7.2. Self-Concept of Abilities

The second factor analysis was conducted on the self-concept of abilities element of the expectancy-value theory. The analysis included 12 survey questions that resulted in 2 factors accounting for 51.68% of variance, with the pattern matrix shown in Table 3. The KMO Measure of Sampling Accuracy value was found to be 0.85. The survey questions "I can incorporate environmental costs and benefits in economic analyses" and "I can incorporate social costs and benefits in economic analyses" were removed from the analysis because they were the only two questions loading onto a third factor. The two factors correspond well to the description of active engagement in SEP in the Conceptual Framework. Both factors have greater than 5 strongly loaded questions, which suggests that they are strong factors [5].

Table 3: Pattern matrix for self-concept of abilities element

Survey Question	TBL Understanding	SE Design Process
I understand the short-term social costs and benefits associated with engineering projects.	0.79	
I understand the long-term social costs and benefits associated with engineering projects.	0.80	
I understand the short-term environmental costs and benefits associated with engineering projects.	0.66	
I understand the long-term environmental costs and benefits associated with engineering projects.	0.59	
I understand the short-term economic costs and benefits associated with engineering projects.	0.69	
I understand the long-term economic costs and benefits associated with engineering projects.	0.81	
I understand the interdependency among the social, environmental, and economic elements of engineering projects.	0.55	
I can apply sustainable engineering practice throughout the engineering design process.		0.76

Survey Question	TBL Understanding	SE Design Process
I can identify experts in areas where my own knowledge is not adequate to address sustainable engineering issues.		0.68
I can define sustainability specifications for projects.		0.82
I can find information to assess a project to see if it meets sustainability specifications.		0.53
I can appropriately engage all types of stakeholders involved in a project.		0.52

The Cronbach's alpha values were found to be 0.88 and 0.81 for the TBL Understanding and SE Design Process factors, respectively. Provided the strong factor loadings and estimates of reliability, both factors can be considered to be acceptable. The two factors are correlated, with a correlation coefficient of 0.46.

7.3. Subjective Task Value

The third factor analysis was conducted on the subjective task value element of the expectancy-value theory. The analysis included 16 survey questions that resulted in 2 factors accounting for 51.8% of variance with the pattern matrix shown in Table 4. The KMO Measure of Sampling Accuracy value was found to be 0.89. The survey question "My classmates are more interested in sustainable engineering practice than I am" was removed from the analysis as it did not load to any factors in the pattern or structure matrix. The questions on intrinsic value and utility value were retained in the first factor, Value. SEP, as defined for this study, corresponds to the engineering profession, which may be why the intrinsic and utility value questions loaded to one factor. The Value factor has 12 strongly loaded items, while the Relative Cost factor has only 3 strongly loaded items.

Table 4: Pattern matrix for construct subjective task value

Survey Question	Value	Relative Cost
I want to be enrolled in a sustainable engineering practice course.	0.80	
I would prefer to learn about sustainable engineering more than any other engineering concept.	0.73	
I enjoy solving problems that incorporate complex social, environmental, and economic elements.	0.75	
My goal is to become a leader in sustainable engineering practice.	0.82	

Survey Question	Value	Relative Cost
I want to apply sustainable engineering practice to every project I work on.	0.85	
I want to ensure that projects contribute towards the development of communities that are impacted by projects.	0.78	
I often discuss sustainable engineering topics with my classmates.	0.59	
I need to learn about sustainable engineering now to be successful in my career.	0.65	
The ability to assess the social, environmental, and economic elements of projects is a useful skill that will make me stand out to potential employers.	0.57	
Learning about sustainable engineering practice is necessary to be a responsible engineer.	0.72	
The application of sustainable engineering practice creates better engineering solutions.	0.70	
I will not work for companies that do not value sustainable engineering practice.	0.53	
Fully incorporating sustainable engineering practice into a real-world project is too expensive to be practical.		0.91
Fully incorporating sustainable engineering practice into a real-world project requires too much time to be practical.		0.88
Technical engineering topics are more important to learn about than sustainable engineering practice.		0.41
Engineering professional skills are more important to learn about than sustainable engineering practice.		0.51

The Cronbach's alpha values were found to be 0.92 and 0.80 for the Value and Relative Cost factors, respectively. Provided the strong factor loadings and estimates of reliability, both factors can be considered to be acceptable. The two factors are correlated, with a correlation coefficient of -0.41.

8. CONCLUSIONS

The proposed survey instrument provides measure students' motivation to engage in SEP includes 3 open-ended questions and 40 closed-ended questions. As determined by the exploratory factor analyses, the instrument measures 7 underlying factors. The development process of the survey instrument and the think-aloud interviews provide evidence for face validity and content validity. However, further research is needed to assess criterion and construct validity. The current research is limited by the sample size and characteristics as there are some differences between the sample and the Canadian undergraduate engineering student population.

The reliability estimates obtained by the factor analyses suggest that the development of additional questions on the stereotypes and previous experiences element and the Relative Cost factor may improve reliability. Overall, the survey considers the complexities of students' motivation and of SEP in a single instrument.

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