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Work-in-progress – Incorporating sustainable development fundamentals in the first year engineering program

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Work-in-progress – Incorporating sustainable development fundamentals in the first year engineering program

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Abstract. In this work-in-progress paper, the authors propose an instrument to measure sustainable development literacy in first year engineering students, and based on the outcomes of the survey; implement a strategy to train freshman-engineering students on the fundamentals of engineering for sustainable development. Traditionally, first year engineering programs teach freshmen students the engineering fundamentals that will help them succeed in more advanced and specialized engineering courses. Since the United Nations Conference Declaration in the Human Environment in 1972, and the subsequent Declaration of Rio de Janeiro in 1992, the topic of Education in Sustainable Development has become increasingly important. In further events, The United Nations Educational Scientific and Cultural Organization (UNESCO), called for the Decade of Education for Sustainable Development from 2005 to 2015. This worldwide reflection is creating a new engineering education culture. Engineering educators are observing significant shifts in societal expectations of the engineering profession to help address immediate and longer-term sustainable development challenges. The World Commission on Environment and Development defined in 1987 sustainable development as “the technology development that meets the needs of the present for people without compromising the ability of future generations to meet their own technological needs”. Society, economy and environment are the three fundamental dimensions of sustainable development. This work-in-progress paper studies the process to introduce the sustainable development fundamentals in first year engineering programs.

Embedding sustainable development thinking in design thinking incorporates new mentalities in engineering design towards a societal commitment to find an optimal balance of the fundamental dimensions of sustainable development. Engineers will be trained to have a mentality that has completely integrated the convergence of societal responsibility with technical performance in all their engineering work. Additionally, systems thinking is seen as a powerful tool to help incorporate multidimensional analysis with complex interactions between the three fundamental dimensions in sustainable development. An assessment of this technique performed on a large body of first year engineering students is analyzed for future actions to improve the questionnaire, including suggestions from industry, academia and different social representative groups. The assessment shows the effectiveness of the pedagogical technique used.

Introduction

The United Nations Environment Programme Industry and Environment Centre (UNEPIE), in conjunction with the World Federation of Engineering Organizations (WFEO), the World Business Council for Sustainable Development (WBCSD), and the French Ecole des Ponts, hosted a conference in Paris in 1997 on the topic of 'Engineering Education and Training for Sustainable Development' [1]. The findings were that "many practicing engineers currently have no education in sustainable development. In the future, sustainable development should be included in both undergraduate and post-graduate courses. Because the transition to sustainable development must be made in the next 20 years, major changes will be required in ongoing education" and also concluded that “practicing professionals will need retraining".

Educators must explore how the knowledge in design thinking, supported by systems thinking, with a fundamental approach of interdisciplinary areas such as technical, social and economic sciences can be directed to create the platform necessary to train engineering students with a formal and holistic approach of the sustainable development dimensions for society, economy and environment. All this in preparation of the 21st century technological challenges they will encounter in their engineering practice.

Because engineers must introduce sustainable technological transformations with a new mentality, it is necessary to begin incorporating sustainable development thinking conceptually beginning in early years in all areas of engineering curricula. This can be done with an approach to design thinking. In order to resolve the optimal equilibrium between the three fundamental dimensions of sustainable development - society, economy, and environment - systems thinking should be included in parallel so fundamentally, each of the three sustainability dimensions can be considered as a complex system with a holistic perspective. Metrics on literacy of sustainable development in first year engineering students is a solid baseline to define the required learning objectives.

None of the sustainable development assessment methodologies developed so far in the United States assesses specific literacy in first year engineering students. Previous studies performed assessed general sustainability concepts rather than a more focused assessment relevant to understanding sustainable development from an engineering point of view.

Identifying the gaps

This measuring instrument should be given to freshman engineering students at the beginning of the semester with the objective to:

1. Identify critical lack of fundamental knowledge in sustainable development.
2. Develop the learning objectives and the corresponding set of lectures/activities to introduce students to sustainable development fundamentals.
3. Execute a second survey in the same first year engineering student body at the end of the first year and after the training has been implemented
4. Compare results of first and second surveys.

The outcomes of the study will help associate academic needs with the necessary faculty training in a way that instructors are well prepared to present lecture materials for fundamentals in sustainable development. Particularly, instructors will be able to incorporate systems thinking and design thinking in an interdisciplinary prospective. Additionally, outcomes will give foundations to advance research and education in sustainable development in engineering. The developed learning objectives for the introduction to sustainable development in engineering practice follow:

a. Recognize what sustainable development is in engineering practice.
b. Discuss the basics of the historical development and societal importance of sustainable development in engineering.
c. Identify the three main dimensions for sustainable development
    I. Society
    II. Economy

III. Environment

d. Discuss what encompasses each of the three sustainable development dimensions.
e. Describe how the three sustainable development dimensions can achieve a holistic balance without compromising societal progress and advancement.
f. Explain what engineering systems thinking is.
g. Applying systems thinking, discuss the complexity of a holistic equilibrium of the three sustainable development dimensions both locally and globally as applied to the engineering design methodology
h. Interpret what the net present value of an engineering project is.
i. Explain how to incorporate severe weather disaster prevention measures in urban development projects.
j. Explain what life cycle assessment of an engineering design is.
k. Explain what sustainable return of investment is.
l. Explain what circular economy is.

What has been done (literature review)

T. Waas, J. Huge, T. Block, T. Wright, F. Benitez- Capistros, and A. Verbruggenin [2], indicated that since the 1990's many substantial and often promising sustainability assessments and sustainability indicators efforts have been made. They demonstrated that sustainability assessment and sustainability indicators could be powerful decision-supporting tools that foster sustainable development by addressing three sustainability decision-making challenges: interpretation, information structuring, and influence. They concluded however, that better practices and a broader shared understanding are still required. In addition, in their work, they framed sustainable assessment and sustainable indicators in the context of sustainable development as a decision-making strategy introducing both fields along with several essential aspects in a structured and comparable manner.

T. M. Koontz, A. Zwickle, K. M. Slagle, J. T. Bruskotter, [3], developed a 16-question assessment with multiple choice answers through soliciting expert input, focus groups, pilot testing, distribution via a large-scale online survey, and analysis using item response theory. The questionnaire covered foundational concepts of the environmental, economic, and social domains within the topic of sustainability, and it presented an initial effort to quantify knowledge of the broad and abstract concept of sustainability by assessing the sustainability knowledge of an undergraduate population. This work was not however targeted specifically to undergraduate engineering population. They plan to continue refining these questions to better differentiate between students with higher levels of knowledge and to replace those with answers that may change over time.

A. L. Carew and C. A. Mitchell [4] set a comparison point with the Institution of Engineers in Australia. The authors mentioned that engineering professionals in Australia - and internationally - are coming under increased pressure to practice engineering more sustainably. In response to this pressure, the Institution of Engineers in Australia has updated the procedure for accreditation of the engineering baccalaureate to ensure inclusion of sustainability learning. In order to graduate, Australian engineering students must now 'understand sustainability'. Their paper reports a synthesis of the literature on sustainability and its understanding, and an empirical investigation into sustainability concepts held by a group of chemical engineering undergraduate students at the University of Sydney. During the synthesis, it was examined what it might mean for a student to understand sustainability by deriving a suite of sustainability principles and describing the component parts of an expert-like understanding of sustainability. In the investigation, students' written responses to the question “in your own words, what is sustainability?” were analyzed using a modified version of the Structure of Observed Learning Outcomes (SOLO) taxonomy. The SOLO analysis revealed broad structural variation in the way Chemical Engineering students understood sustainability. The study was not focused to first year engineering students.

J. Segalasa, D. Ferrer-Balash and K.F. Mulder [5], concluded that since the 1990s, courses in sustainable development were offered in European technological universities. After some years of practice, there is increased interest in the evaluation of the most effective ways for teaching sustainable development. In this paper, authors introduce the use of conceptual maps as a tool to measure the knowledge acquired by students when taking a sustainability course. These measurements were carried out using a sample of more than 700 European students. Before a course would start, the students’ previous knowledge on sustainability would be measured; once the students have completed the course they would be evaluated again. By comparing conceptual maps drawn by each student, the improvement of the students' knowledge is evaluated. This paper shows the measuring process and points out the suitability of using conceptual maps for research in education. Moreover, the correlation between the learning outcomes the pedagogical techniques used in each course may indicate the effectiveness of the pedagogical strategies in education for sustainable development.

M. Shriberg [6], analyzed efforts to measure sustainability in higher education across American institutions. This study identified benchmark leaders and best practices for communicating common goals, experiences, and methods to measure progress towards the concept of a sustainable campus. He concluded that sustainability education, as a central part of curricula, should be pursued. No metrics of sustainability literacy in first year engineering students was established.

T. M. Bramald, O. Heidrich, and J. A. Hall [7], reviewed three different exercises to encourage students understand a holistic approach of the engineering for sustainable development, and to develop sustainability literacy among future engineers. (1) Students wrote qualitative comments of an exploration of their own campus identifying stereotypical civil engineering issues (such as construction trends); (2) Students ranked the importance of components of a sustainable community; (3) Different groups of students were led through a discussion about a systems approach to engineering and the impact in their engineering specialty. The three exercises seemed to succeed in contributing towards future engineers having a broader understanding of engineering for sustainable development. Systems thinking interconnects elements and identifies causalities and feedback loops.

A. Nyström and M. Svanström [8] concluded that systems thinking has been applied in both natural sciences and social sciences. In social sciences, systems thinking has helped to identify improvement opportunities in organizations, therefore, sustainable development problems can be illustrated with systems theory and causal loop diagrams using systems analysis.

A. Wiek, L.Withycombe, CL. Redman [9] Described systems thinking as "the ability to collectively analyze complex systems across different domains (society, environment, economy, etc.), and across different scales (local to global). Thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks".

In further analysis, D. Shields, F. Verga, and G. A. Blengini [10], studied how systems thinking helps understand that sustainable development provides a framework for addressing different types of controversial, multifaceted issues and is often discussed in terms of the triple bottom line.

Habron et al. [11] performed a study with students who were learning systems thinking related to sustainable development. He interacted with students to continuously adapt the course contents, and he found that students failed to develop complex systems thinking mainly because teachers assessing the students were not prepared for the shift in the teaching approach, i.e. student-centered learning, disagreed on how to assess the learning, and failed to utilize feedback from the students. However, using system characteristics and the systems thinking capabilities in relation to technical systems thinking in a sustainability context, the learning objectives can be interpreted within the framework of the three dimensions of sustainable development – society, economy and environment.

M. Svanstro, F. J. Lozano-Garcia, and D. Rowe [12] discussed learning outcomes for education for sustainable development. These included systemic or holistic thinking, the integration of different perspectives, skills such as critical thinking, change agent abilities and communication, and finally different attitudes and values. They concluded that engineering professionals should not only be knowledgeable and skillful in their disciplines but also should resonate with the systemic and complex frame of reference of sustainability.

R. Mckeown and C. Hopkins [13] briefly described differences and similarities between environmental education and Education for Sustainable Development (ESD), examining four levels activity: (l) disciplinary; (2) whole school; (3) educational system; and (4) international or global influence. They concluded that given the breadth of support needed to fulfil the formal education components of ESD, improving quality basic education and reorienting education to address sustainability consortiums of partners is necessary to create comprehensive ESD programs; disciplines alone cannot accomplish it.

V. Nolet [14], explored sustainability as an emerging paradigm for preservice preparation of teachers. He concluded that sustainability education represents a new paradigm for the preparation of teachers and can stimulate a conversation about the role of teacher education in the creation and solution of the challenges for global environmental and social justice.

N. A. Ashford [15] addressed the major challenges engineering education for sustainable development encounters, namely: How can multi- and trans-disciplinary teaching and research coexist in a meaningful way in today's university structures? Does education relevant to sustainable development require its own protected incubating environment to survive, or will it otherwise be gobbled up and marginalized by attempting to install it throughout the traditional curriculum? What roles can national and European Union governments have in accelerating the needed changes? How can it be made safe for courageous students to take educational paths different from traditional tracks, if the technical options exist to do so? What can one learn from comparative analysis of universities in different nations and environments? Professor Ashford concluded that although the established engineering disciplines continue to provide some useful advances, the approaching portfolio is under-represented in multi-disciplinary and trans-disciplinary scholarship and pedagogy. Emphasizing that without clear, vocal, and strong continuous leadership and rewards for a "second track" of problem solving in these institutions, progress will continue to be slow.

C. I. Desha., K. Hargraves, and M. H. Smith [16]., presented a case for engineering departments to undertake rapid curriculum renewal towards engineering education for sustainable development (EESD), to minimize the risk of having the department exposed to rapidly shifting industry requirements, government regulations and program accreditation. The timeframe for engineering educators to equip professionals with new skills related to environmental management and sustainable development is converging with the timeframe for the engineering community to successfully act to avoid irreversible damage to the ecosystems. They concluded that there is little evidence of a shift to engineering education in sustainable development in engineering curriculum worldwide. This situation, combined with the lack of existing engineering programs that develop these attributes, has created a time lag dilemma for engineering educators to address. Ultimately, within the next 20 years, most engineering departments will make the transition to EESD as society addresses the challenges of sustainable development.

L. Kamp [17] stated that it is becoming clearer that technological innovation can be a useful tool for achieving sustainable development. Therefore, making technology students aware of these boundaries and tools is an important educational task for universities. Such education should include two subjects. (1) Give students insight into the concepts of sustainable development. What is sustainable development? What are sustainability problems? What are the causes of these problems? Which strategies and approaches for solving them are available? (2) Give engineering students insight into the technology development process. How does the technology development process work? Which factors influence and steer it? What is the influence of technology on society and on sustainable development? The Technology Assessment group at Delft University of Technology in the Netherlands developed the contents of introductory and specialization courses. Even though over 150 students choose the sustainable development graduation specialization, they found that integrating sustainability fully into the curricula and changing the engineering paradigm requires support from leading scientists, lecturers and the university board.

Steinemann [18] presented an approach for implementing sustainability in higher education. In order to help students learn how to analyze sustainability, work with decision makers, and put classroom knowledge into practice, this course had an emphasis on problem-based learning, so students acquire critical cognitive skills and professional skills as they tackle complex, interdisciplinary, and real-world problems. Problem-based learning provided a motivating context for learning and for acquiring practical problem-solving skills. Moreover, implementing sustainability through PBL allowed students to create projects that helped the campus community, and that bridged education and practice.

Methodology

Within the immediate two previous years, the authors have performed prelim studies to 816 students of the first year engineering program at Texas A&M University (IRB ID: IRB2018-1594). Table 1 lists details of the questionnaire©.

Table 1. Preliminary questionnaire©

1. Give the formal definition of sustainable development	6. Explain how the three integral dimensions of sustainable development can operate in balance	12. Define the Net Present Value of and engineering project
2. Where and when the topic of sustainable development began being into context?	7. Why engineering for sustainable development is a multidisciplinary area	13. Explain how the engineer in charge of a urban development project can incorporate in the project design process severe weather disaster prevention measures
3. Why engineering educators are observing significant shifts in societal expectations of engineering?	8. Give a formal definition of Design thinking 9. What are the five (5) steps of design thinking?	14. Define the life cycle of and engineering product

4. Name the three fundamental dimensions of sustainable development	10. What is the 6th factor in the sustainable analysis of design thinking	15. Define sustainable return on investment (S-ROI) for an engineering project
5. Why systems thinking is a powerful tool to incorporate multidisciplinary analysis with complex interactions?	11. Explain how sustainable development can be embedded into design thinking	16. Define Circular economy

Interestingly, the outcomes show that incoming first year engineering students completely lack the sustainable development fundamentals required to comprehend, at a more advanced level, the potential contributions they can make for sustainable engineering designs and advances during their engineering practice. However, after they were trained with the learning objectives developed based on the prelim survey, in a second survey, students show significant progress in understanding the sustainable development fundamentals required to develop realistic solutions using sustainable thinking during their training in more advanced engineering courses.

In order to measure Sustainable Development literacy and following the previously described plan, Dr. Lara gave his first-year engineering students the questionnaire and requested them just to answer, "I do not know" if they had no idea of the correct response. With the assurance that there were going to be no punishment actions if a student does not know what he/she was going to be asked in the questionnaire, the following bar-plots show that in general students know very little

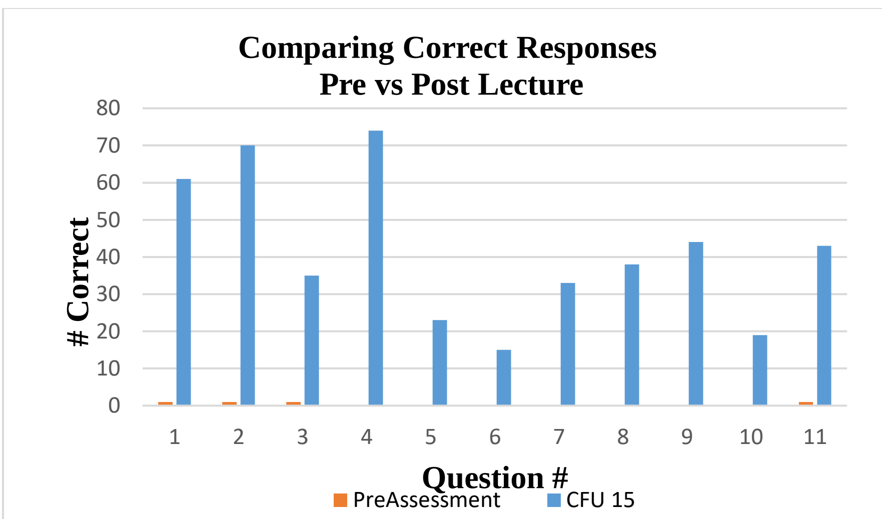

Figure 1. Survey questionnaire given to 384 first year engineering students of ENGR 112 on spring semester of 2018 (IRB ID: IRB2018-1594). Amber bars show correct responses before training (Pre-assessment). Blue bars show correct responses to a check for understanding (CFU) after the 2 hours training. The number of responses depicted corresponds to a class section of 96 students each.

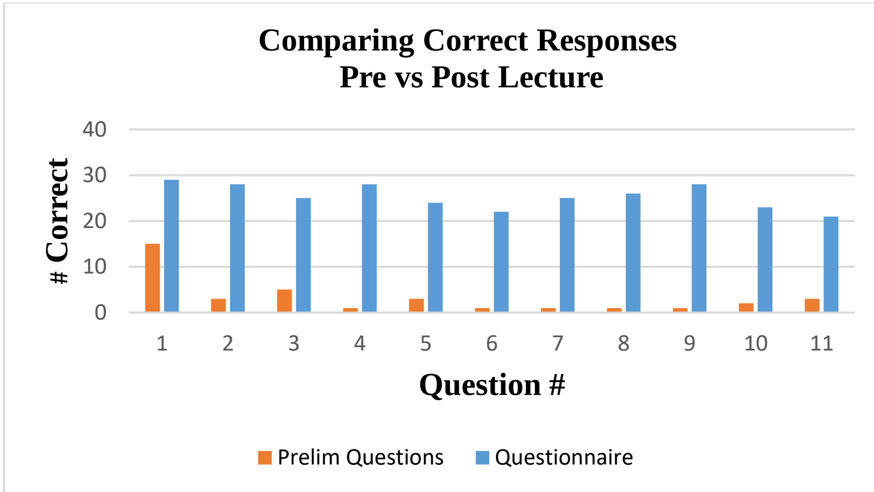

Figure 2. Survey questionnaire given to 36 first year engineering students of ENGR 112 on summer semester of 2018 (IRB ID: IRB2018-1594). Amber bars show correct responses before training (Pre-assessment). Blue bars show correct responses to the questionnaire after the 2 hours training.

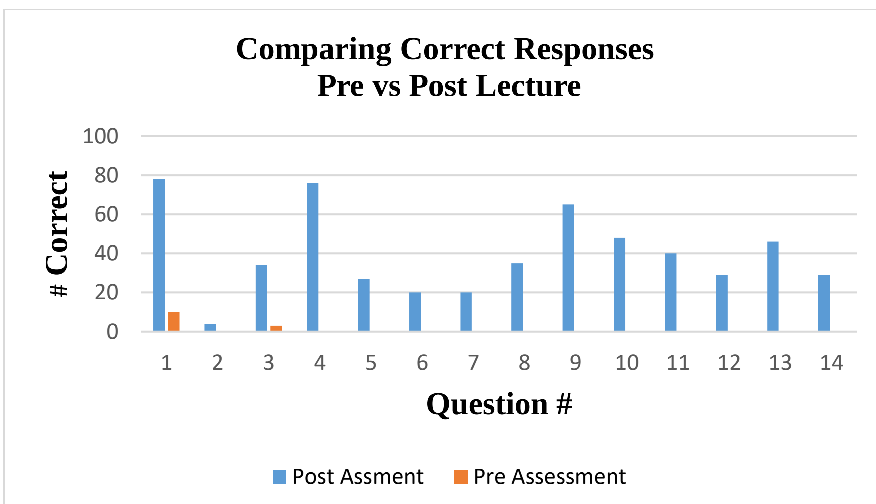

Figure 3. Survey questionnaire given to 362 first year engineering students of ENGR 112 on fall semester of 2018 (IRB ID: IRB2018-1594). Amber bars show correct responses before training (Pre-assessment). Blue bars show correct responses to the questionnaire after the 2 hours training. The number of responses depicted corresponds to a class section of 96 students each.

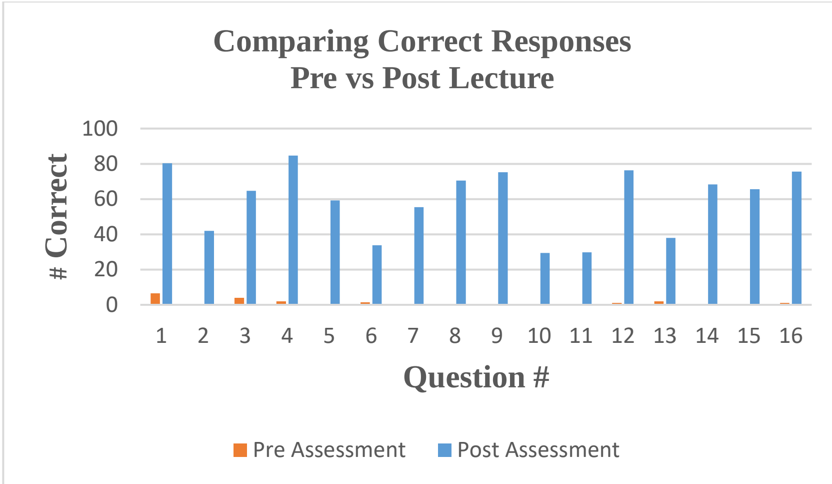

Figure 4. Survey questionnaire given to 285 first year engineering students of ENGR 102 on fall semester of 2019 (IRB ID: IRB2018-1594). Amber bars show correct responses before training (Pre-assessment). Blue bars show correct responses to the questionnaire after the 2 hours training. The number of responses depicted corresponds to a class section of 96 students each.

or nothing of sustainable development initially. After a short 2 hours micro-lecture of the very basic fundaments of sustainable development covering the learning objectives previously described, the same pre-assessment questionnaire was given to students with the very encouraging outcomes shown in Figures 1, 2, 3 and 4. Figure 3 shows the outcomes after three additional questions were included to the first questionnaire. Figure 4 depicts 16 questions after two more questions were added. Table 1 provides details of all 16 questions assessed.

Results, conclusions and future work

The outcomes of the prelim survey depicted in figures 1—4, show that after a consciously prepared and objectively oriented short 2-hour lecture for training, first-year engineering students learn within acceptable levels the fundaments of Sustainable Development. More importantly, after the lecture, several students approached the instructor asking how they could learn more about the topic and the possibilities to formally incorporating engineering for sustainable development into their required curricula. In all figures, the number of responses depicted is normalized to a class section of 96 students each.

The authors will work on the preparation of the learning objectives of a course that will train first year engineering students with the goals that follow:

-Do first year engineering students identify the definition of sustainable development and its principles and fundaments?

-Do first year engineering students recognize what the industry and societal expectations are, both locally and globally?

-What do first year engineering students know about sustainable development thinking incorporated in design thinking with a systems thinking holistic approach?

-How can a first-year engineering student practice and get motivated in learning sustainable development thinking?
-How will a mid-year engineering student develop a new mentality and skills with sustainable development commitment?
-How will a senior engineering student carry on a new perspective of engineering practice with a fully integrated sustainable development thinking in his/her college training?
-Is the First Year Engineering Program faculty trained to teach the complex holistic approach of sustainable development fundamentals?
-Is a course in fundamentals of sustainable development with simple language enough to train first year engineering students the principles required to engage students into a more comprehensive study related to sustainable development?

For future assessments, sustainability assessment and sustainability indicators can be powerful decision-supporting tools that foster sustainable development knowledge in first year engineering programs by addressing three sustainability decision-making challenges: interpretation, information structuring, and influence. The authors propose an assessment of the course and modules that will follow a quasi experimental methodology. As part of the assessment plan, an instrument that measures conceptual thinking in sustainable engineering will be developed and administered pre and post course to the students to gauge their overall gains in knowledge following the methodology outlined by Hake [19].

References

[1] JCEETSD (1997) Joint conference report, Paris 1997. UNEP, WFEO, WBCSD, ENPC (1997), *Engineering Education and Training for Sustainable Development*, Report of the joint UNEP, WFEO, WBCSD, ENPC Conference, Paris, France, 24–26 September 1997.
[2] T. Waas, J. Hugé, T. Block, T. Wright, F. Benitez-Capistros, and A. Verbruggenin Sustainability Assessment and Indicators: Tools in a Decision-Making Strategy for Sustainable Development. *J. Sustainability* 2014, *6*(9), 5512-5534
[3] T. M. Koontz, A. Zwickle, K. M. Slagle, J. T. Bruskotter, Assessing Sustainability Knowledge of a Student Population: Developing a Tool to Measure Knowledge in the Environmental, Economic, and Social Domains. *International Journal of Sustainability in Higher Education* Vol 15 (4), 375-389.
[4] A. L. Carew and C. A. Mitchell, Characterizing undergraduate engineering students understanding of sustainability. *J. European Journal of Engineering Education.* Vol 27, 2002, Issue 4.
[5] J. Segalàsa, D. Ferrer-Balasb and K.F. Mulderc. Conceptual maps: measuring learning processes of engineering students concerning sustainable development. *European Journal of Engineering Education.* Vol. 33, No. 3, June 2008, 297–306
[6] M. Shriberg. Institutional assessment tools for sustainability in higher education: strengths, weaknesses, and implications for practice and theory. *J. Higher Education Policy* 15 (2002) 153-167.
[7] T. M. Bramald, O. Heidrich, and J. A. Hall., Engineering education for sustainable development, *Cambridge, UK.* September 22-25, 2013 6(2):203-218.
[8] A. Nyström Claesson, M. Svanström., Systems thinking for sustainable development -

What does it mean and how is it formed? *Proceedings EESD 2013.* Paper 71.
[9] A. Wiek, L. Withycombe, CL Redman., Key competencies in sustainability: a reference framework for academic program development. Integrated Research Systems for Sustainability Science. *Sustainability Science,* 6(2): 203-218. 2011.
[10] D. Shields, F. Verga, G. A. Blengini., Incorporating sustainability in engineering education, *International Journal of Sustainability in Higher Education*. Vol 15 No. 4, 2014 pp 390-403.
[11] Habron G., Goralnik L., Thorpe L., Embracing the learning paradigm to foster systems thinking, *International Journal of sustainability in Higher Education*, vol. 13, pp. 378-393, 2012.
[12] M. Svanstro¨, F. J. Lozano-Garcıa, and D. Rowe International Journal of Sustainability in wHigher Education. *Learning outcomes for sustainable development in higher education* Vol. 9 No. 3, 2008 pp. 339-351
[13] R. Mckeown and C. Hopkins., Moving Beyond the EE and ESD Disciplinary Debate in Formal Education. *Journal of Education for Sustainable Development* 2007 1: 17
[14] V. Nolet, Preparing Sustainability-Literate. *J. Teachers College Record,* v111 n2 p409-442 2009.
[15] N. A. Ashford., Major challenges to engineering education for sustainable development. *International Journal of Sustainability in Higher Education,* Vol. 5 Iss 3. 2004 pp. 239 – 250.
[16] Desha C. J., Hargroves, K., M. H. Smith "Addressing the Time Lag Dilemma in Curriculum Renewal towards Engineering Education for Sustainable Development". *International Journal of Sustainability in Higher Education,* Vol. 10 Iss: 2, 2009. pp.184 – 199.
[17] L. Kamp, "Engineering Education in Sustainable Development at Delft University of Technology," *Journal of Cleaner production* 14 (2006)928-931.
[18] A. Steinemann. Implementing Sustainable Development through Problem-Based Learning: Pedagogy and Practice, *Journal of Professional Issues in Engineering Education and Practice © ASCE / October 2003 / pp-217.*
[19] Hake, R. R. Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American journal of Physics*, *66*(1), 64-74. 1998.