

Teaching Students to Appreciate the Global Challenges of Sustainability

Sheila K. Lascano

Universidad Técnica Federico Santa Maria, Santiago, Chile, sheila.lascano@usm.cl

Jaime Nuñez

Universidad Técnica Federico Santa Maria, Santiago, Chile, jaime.nunez@usm.cl

Ivan E. Esparragoza

Penn State University, Media, PA, USA, iee1@psu.edu

Linda C. Schmidt

University of Maryland, College Park, MD, USA, lschmidt@umd.edu

Robert L. Nagel

James Madison University, Harrisonburg, VA, USA, nagelrl@jmu.edu

ABSTRACT

Sustainability is increasingly becoming an important topic in engineering education. The responsibility of engineers to find sustainable solutions for worldwide challenges is evident; therefore, new graduates need to develop the necessary knowledge, skills, and attitude to find viable, desirable, and feasible solutions by balancing the three pillars of sustainability. One of the main challenges in engineering education is, however, to identify the appropriate model to educate students in this field. The main goal of the educational model proposed in this paper is to design a methodology based on the case study approach to assist students with comprehending and assessing multi-dimensional and global sustainability challenges in multiple contexts. This paper summarizes the proposed project to accomplish this goal. The work is planned with international collaboration with the purpose of identifying sustainability perspectives based on geographical, educational, and cultural differences.

Keywords: Sustainability, engineering education, case studies

RESUMEN

La sostenibilidad se está convirtiendo cada vez más en un tema importante en la enseñanza de la ingeniería. La responsabilidad de los ingenieros para encontrar soluciones sostenibles para los desafíos en todo el mundo es evidente; por lo tanto, los nuevos graduados tienen que desarrollar los conocimientos, habilidades y actitudes para encontrar soluciones viables, deseables y factibles mediante el equilibrio de los tres pilares de la sostenibilidad. Sin embargo, uno de los principales retos en la enseñanza de la ingeniería es identificar el modelo adecuado para educar a los estudiantes en este campo. El objetivo principal de esta propuesta educativa es el diseño de una metodología basada en el método de estudio de casos para ayudar a los estudiantes a comprender y evaluar los desafíos multidimensionales y globales de sostenibilidad en múltiples contextos. Este escrito resume el proyecto propuesto para lograr este objetivo. El trabajo propuesto se ha previsto con la colaboración internacional con el propósito de identificar las perspectivas de la sostenibilidad basados en las diferencias geográficas, educativas y culturales.

Palabras claves: Sostenibilidad, educación de ingeniería, casos de estudio

1. INTRODUCTION

Sustainability is a ubiquitous, complex, and poorly defined concept; however, it is a key competency for designers, engineers, and technical professionals (de Vere et al., 2011). Unfortunately, today's engineering students have a narrow view of sustainability, thinking of it as simply environmental impact or energy efficiency (Allenby & Rajan, 2012) without taking into account the social and economic contexts (multidimensional context of sustainability). In addition, a review of strategies for teaching sustainability reveals that approaches tend to focus primarily on a single local context of sustainability instead of a holistic approach (Arsat et al., 2011).

While there is a recognition of the importance of sustainability in education and the understanding of sustainability in multiple contexts, most current curricula graduate engineers who are "inadequately trained to be effective at socially responsible design" (de Vere et al., 2011). In other words, engineering education has traditionally focused on technical performance at the expense of understanding the impact in the social dynamics, as well as the global implications of engineering practice.

The main pedagogical technique of this educational model is a methodology based on the case study approach to assist students with comprehending and assessing multi-dimensional and global sustainability challenges in multiple contexts. The idea is to achieve not only the learning objectives in the subjects related to engineering design and energy conservation but also to develop professional skills, including sustainability awareness in its comprehensive form, as part of the growth of the graduate profile.

The team will accomplish this goal by creating, testing, and assessing a series of case study modules of the same product that are conducted in different locations in the Americas and compare them to identify factors contributing to sustainability differences related to location. This evaluation will be accomplished by applying case studies in different stages of the curriculum and in courses related with design and manufacturing, production and quality management, thermodynamics, heat transfer, combustion engines, and transport. The research will be addressed through a mixed methodological approach that combines quantitative and qualitative techniques, designed to measure the results in terms of achievement and observable changes in the domain of interpersonal skills of students and instructors implementing this methodology.

The following results have been proposed for this project: (i) a formal methodology to assist students to comprehend and assess multi-dimensional and global sustainability challenges in multiple contexts and to measure, periodically and longitudinally throughout the curriculum development, learning achievement and interpersonal skills stated in the graduate profile; (ii) a repository of case studies that will be published on-line; (iii) a workshop to train higher education instructors; (iv) the design of schemes to the formal implementation of the multi-dimensional sustainability concept in the engineering curricula. In addition, the project seeks to foster and strengthen multinational cooperation as a powerful means to promote a global and holistic approach to sustainability.

2. BACKGROUND

This initiative started during the Pan-American Advanced Studies Institute (PASI) on Sustainability that took place in Universidad del Norte in Barranquilla, Colombia during the summer of 2013. A group of scholars from different countries in the Americas got together to explore collaborative opportunities in this field. The group formed to discuss ideas in engineering education and concluded that work has to be done in this area to make a complex issue as sustainability easy to understand and use by the students when developing engineering solutions. The need identified by the group was well aligned with an effort to enhance the curriculum based on technical and professional competencies of one of the institutions represented in the PASI. As a result, the educational project presented here is also part of the tasks assumed by the Department of Mechanical Engineering at Technical University Federico Santa Maria (UTFSM) in Chile with the aim of ensuring the competitiveness and quality of its engineering program in response to the assessment conducted in 2011 by the National Commission on Accreditation. Among the objectives set by the program, those of particular relevance for this work are: (a) to strengthen professional skills and English language in the graduates; (b) to design an integrated curriculum based on competencies to develop technical and professional skills; (c) to use formal mechanisms to assess periodically

the progressive learning of technical content of engineering concepts and the progressive development of professional skills and English language proficiency.

The aim of this work is to develop a methodology based on case study approach that effectively exposes students to knowledge, skills, and attitudes required for global competitiveness in sustainability challenges. This active learning approach requires students to work in teams solving cases study modules in a way that creates a learning environment that facilitates the development not only of the knowledge of design models and principles but also the development of social, ethical, and management skills relevant to sustainability. This work proposes to incorporate the case study modules in a series of longitudinal courses of the mechanical engineering curriculum at UTFSM. This approach requires formal assessment tools for subject competencies and professional competencies to be developed for longitudinal use throughout the mechanical engineering curriculum.

The team will accomplish this goal by creating, testing, and assessing a series of case study modules of the same product at different institutions in USA (University of Maryland, Pennsylvania State University and James Madison University) and Latin-America (UTFSM in Chile, Universidad del Norte in Colombia). Results will be compared to identify factors contributing to different perceptions of sustainability. This evaluation will be accomplished by applying case studies during different stages of the curriculum, and a set of courses: Introduction to Engineering, Introduction to Engineering Design, Mechanical Design, Production and Quality Management, Thermodynamics, Heat transfer, Combustion Engines, and Transport. The global component will be addressed by collaborative tasks developed between students in the Universities. The research will be addressed through a mixed methodological approach that combines quantitative and qualitative techniques, designed to measure the results in terms of achievement, and observe changes in the domain of interpersonal skills of students and teachers.

This educational approach allows promoting the following aspects in active learning:

- Communication. The use of computer tools for conducting collaborative projects based on case study modules will be required. Students from different institutions working on multinational global sustainability challenges will be required to solve design problems together using available communication technologies. Students will use common communication tools such as Skype, Messenger and email, which should leave a repository of all conversations and information exchange. Students will also document all information platforms used during the project.
- Active Learning. This project is based on the case study approach, which has been considered an active learning methodology where the students investigate a phenomenon within its real-life context.
- Development of professional skills and attitudes. This project will enhance strong analytical skills and practical ingenuity (planning, combining, and adapting). In addition, other attributes as high ethical standards and professionalism, knowledge about the fundamentals and dynamics of globalization, and the ability to work in multicultural/multinational teams will be improved with this experience.
- Development of a methodology that integrates the three contexts of sustainability into the classroom. The case studies will be intended to cover the three dimensions of sustainability—environmental, social, and economical.

3. LITERATURE REVIEW

As quoted by Ballin and Griffin, the term ‘global education’ is as good as any to evoke the whole field. It implies a focus on many different, though overlapping, educational levels from very local and immediate to the vast realities named with phrases such as ‘world society’ and ‘global village’. It implies also a holistic view of education with a concern for children’s emotions, relationships, and sense of personal identity as well as with information and knowledge (Ballin, Griffin, Alexander, & Derby, 1999). Hence, an education in sustainability needs to be holistic covering environmental, economic, and social concerns (Giddings, Hopwood, & O'Brien, 2002; Hopwood, Mellor, & O'Brien, 2005; Pearce, Barbier, & Markandya, 2013). Students should learn to recognize the inherent complexities of real sustainability problems. Barth et al. (2007) state “the development of

key competences is based both on cognitive and non-cognitive dispositions ... and through combining formal and informal learning settings within higher education—as part of a new learning culture—a variety of contexts can be given and competence development can be enhanced.” In addition, Wals and Jickling (2002) stress that sustainability education “concerns cognition, attitudes, emotions, and skills ... and includes deep debate about normative, ethical, and spiritual convictions.”

While there is recognition of the importance of sustainability education and understanding sustainability in multiple contexts, most current curricula graduate engineers who are “inadequately trained to be effective at socially responsible design” (de Vere et al., 2011). Steiner and Posch (2006) describe that “traditional unidirectional educational processes are only of very limited use when educating for sustainable development...” Programs such as Engineers without Borders are of noted benefit; however, they tend not to be integrated into the core curricula which limit student accessibility to these programs. Huntzinger et al. (2007) argue for a change from the traditional education approach to one where an education in sustainability becomes “an integral part of engineering education problems.” Additionally, Huntzinger et al. (2007) stress that “students need not only the knowledge base to generate effective engineering solutions; they need the intellectual development and awareness to understand the impact of their decisions.” This statement is reinforced by (Quadrado et al., 2013)

Figure 1 shows conceptual framework proposed by Arsat et al (2011). The conceptual framework aims to characterize course learning objectives and course contents for sustainability in engineering education (Arsat et al., 2011).

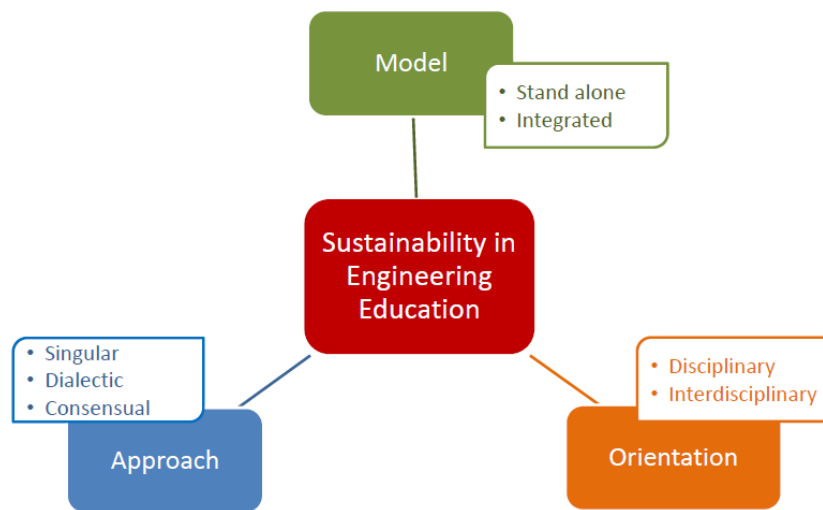


Figure 1. The sustainability in Engineering Education (Arsat et al., 2011)

A review of strategies for teaching sustainability reveals that approaches tend to focus primarily on a single context of sustainability (Figure 2). For example, Lee et al. (2011) in introducing sustainability concepts in lower division engineering core courses, describes their NSF funded educational research project to develop "modules including lectures, in-class activities, hands-on laboratories, and interactive Excel spreadsheets." These modules, however, do not have a global context, and the focus is uni-dimensional with emphasis solely on the environmental context. Price et al. (2012) in “Integrating Sustainability Principles in Undergraduate Engineering Curriculum: A Home for Environmentally Responsible Engineering,” describe a four course sequence (College and Life Skills, Rhetoric and Composition, Sustainability and Its Global Contexts, Introduction to Design) at Rose-Hulman Institute of Technology taken by a cohort of students during the first-year curriculum. These courses, however, still focus primarily on the environmental context of sustainability, and the transferability of this approach is limited due to the multi-course nature of the approach. Beckman et al. (2007) in “Combining educational studies, research and international experiences in sustainable engineering describe,” an undergraduate

and graduate program developed in partnership between University of Pittsburgh, University of Campinas, University of Texas-El Paso, and University of Puerto Rico-Mayaguez to "broaden their [student] perspectives in sustainability" and to teach students to "function collaboratively in cross-cultural environments." Again, however, the focus is in the areas of "green construction and sustainable water use", an important part of sustainability but not the complete context.

Approaches

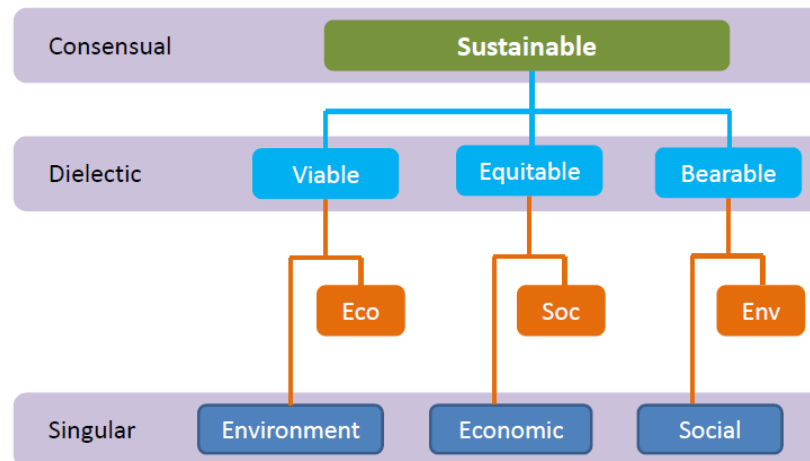


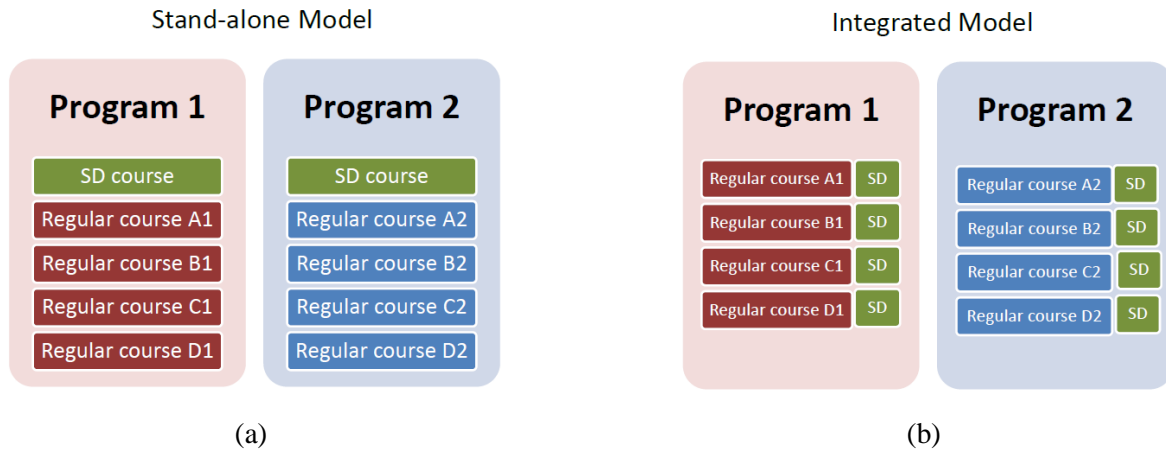
Figure 2. Approaches proposed to implement the sustainable concept in the curricula: Consensual, Dielectric and Singular (Arsat et al., 2011).

A conceptual framework of models for integrating the sustainability concept and orientation (Figure 3) has been introduced by Arsat et al. (2011). This diagram suggests a structured approach to integrate the individually taught topics of sustainability in early courses (the lowest tier) to the holistic treatment of sustainability for students in the later years of a curriculum.

Case study approaches have been effectively implemented as sustainability teaching materials. Some examples are discussed here. A survey of business students showed the efficacy of case study teaching. Erskine and Johnson (2012) surveyed 183 business students in a large Midwestern university to discover how effective they perceived 35 different approaches would be for learning about sustainability; using case studies ranked as one of the "more effective learning strategies" used during the class with a mean rating of 3.69 out of 5.00 for all students and was in the top five preferred strategies for management majors. The most preferred learning strategies involved scholarships, internships, international opportunities, practices implemented at their university and integration of sustainability throughout multiple classes. Case studies have the benefit of providing a lens through which to learn about sustainability. According to Krumdieck,(2011) designing for sustainability is much like learning to design for safety, a field that began in response to disasters such as the Triangle Shirtwaist Factory fire in March 1911 and, more recently, the massive Deepwater Horizon oil spill of 2012. Krumdieck posits that sustainability can only be defined by its failures (e.g., ozone layer depletion leading to a hole) and engineers need to learn a new form of design that mitigates sustainability risks to deal with the new reality. Engineers must learn to exploit synergies across geographical scales (reviewing local, region, and global scale frames of reference), time and social scales, and principles that apply regardless of scale when designing complex systems,

Kumar et al. (2005) describe the integration of sustainability principles through a mechanical engineering curriculum as well as the Sustainable Futures Institute funded by the Sustainable Futures IGERT project. We envision that our modules could be used in a variety of courses throughout the curriculum to supplement current curricular integrations of sustainability as well as provide a starting point for foundational course development in

Models



Orientation

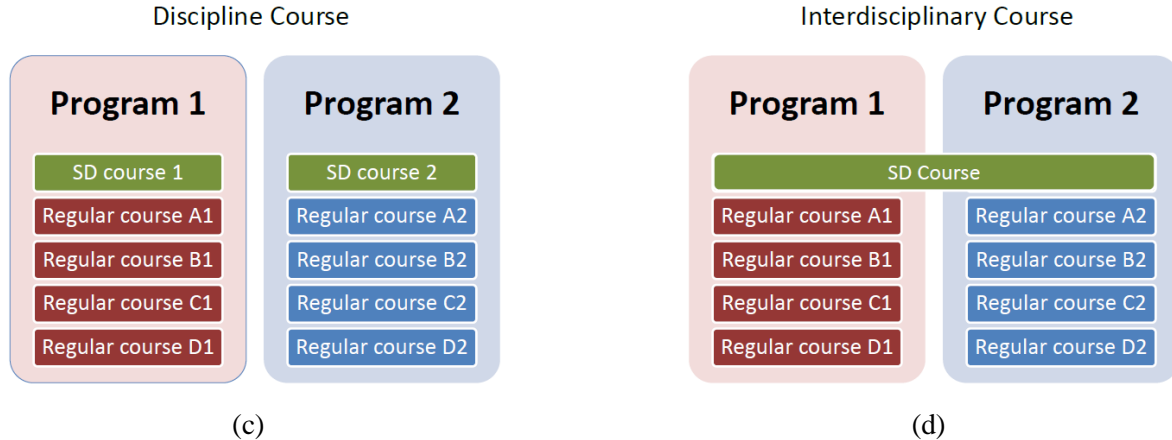


Figure 3: Models and orientation to implement sustainability in engineering Curricula. Models:(a) Stand-alone Model, (b) Integrated Model. Orientation: (c) Discipline Course and (d) Interdisciplinary Course (Arsat et al., 2011).

programs looking to begin teaching sustainability (Kumar et al., 2005). An example where modules have been applied effectively is described by Toprak et al. (2013). Toprak et al. created a blended learning experience (i.e. online materials supplement face-to-face classroom instruction) in a vocational education and training module to teach principles of reducing non-revenue water use and piloted it online (using Moodle) to 125 students from six European countries. Students were generally pleased with the type of learning environment provided to them. Some provided feedback to improve the course, requesting additional case studies.

4. HYPOTHESIS AND OBJECTIVES

This research proposes to use active learning methodologies contextualized in multicultural environments with the aim of addressing the challenges outlined regarding the absence of technical knowledge and professional skills on sustainability in engineering students. The main goal is to enhance the case study approach to teach students to comprehend and assess multi-dimensional, global sustainability challenges throughout the Americas in multiple contexts such that students learn to design sustainable engineering solutions applicable for both local and global contexts. There are two hypotheses of this research: (1) Students who are exposed to systematic learning

experiences based on the case study approach will have improved understanding of all aspects of sustainability. (2) Student interactions across the Americas will result in students learning the applicability of a multi-contextual approach to sustainability.

The following tasks are proposed to achieve this goal:

- Identify a subset of sustainability indices in the environmental, economic, and social domains that are relevant and tractable for graduate and undergraduate students.
- Create meta-analysis case studies on a varied portfolio of products used across the Americas for learning how to comprehend and assess sustainability problems.
- Create an assessment tool that measures student learning of sustainability principles.

5. METHODOLOGY

Locations and research team chosen are strategic as they represent different types of institutions as well as different geographic regions in the Americas. This will be important in developing case studies for our product portfolio as students and faculty at each institution have different ethnographic and economic perspectives as well as different environmental realities.

An industrial advisory board will be put together to advise and provide formative feedback to the project team. The industrial advisory board members will be asked to talk to students at each location to provide an industry view on sustainability following student exploration. Additional activities of the industrial advisory board include: approve product portfolio for the development of case studies, provide sustainability attitudes desired of employees, review results of piloting case studies, help develop strategies as the project progresses, and review final annual reports. The team and the industrial advisory board will meet at least four times per year via video conferencing software.

The following tasks are proposed to commit this project:

1. Recruit an Industry and Community Advisory Board for each Partner location to provide expertise on local realities and formative assessment of project progress.
2. Identify a subset of sustainability indices in the environmental, economic, and social domains that are relevant, tractable and valid for the Americas (e.g. carbon footprint, embedded water)
3. Perform case studies at each research location for products in the team's portfolio. The portfolio is made of products available at each institution but also displaying geographic variety in the location of different life-cycle segments. Possible products include: mobile phones, corn, soda pop (including can and case), and packaging.
4. Perform a meta-analysis by comparing case studies on the same products to identify differences and their sources.
5. Select (or modify) an assessment tool that measures student learning of sustainability principles in a pre- and post-test configuration to evaluate module effectiveness.
6. Develop lesson plans for module deployment in researcher courses in teams that allow online engagement of students from different locations.
7. Pilot a comparative case study in partner institutions and refine deployment instructions.

5. ACTION PLAN

This initial educational research provides confidence that the approach proposed of blended learning materials with collaborative peer-to-peer activities between countries based on sustainability concepts will be effective. Our plan, shown graphically in Figure 4, consists of four fundamental components: (1) Research Existing Case Studies and Case Study Pedagogy in Engineering, (2) Research State of the Art in Computational Indices, (3) Research Product Portfolio Options Relevant to Geographic Locations, and (4) Research Existing Assessment Metrics for Sustainability.

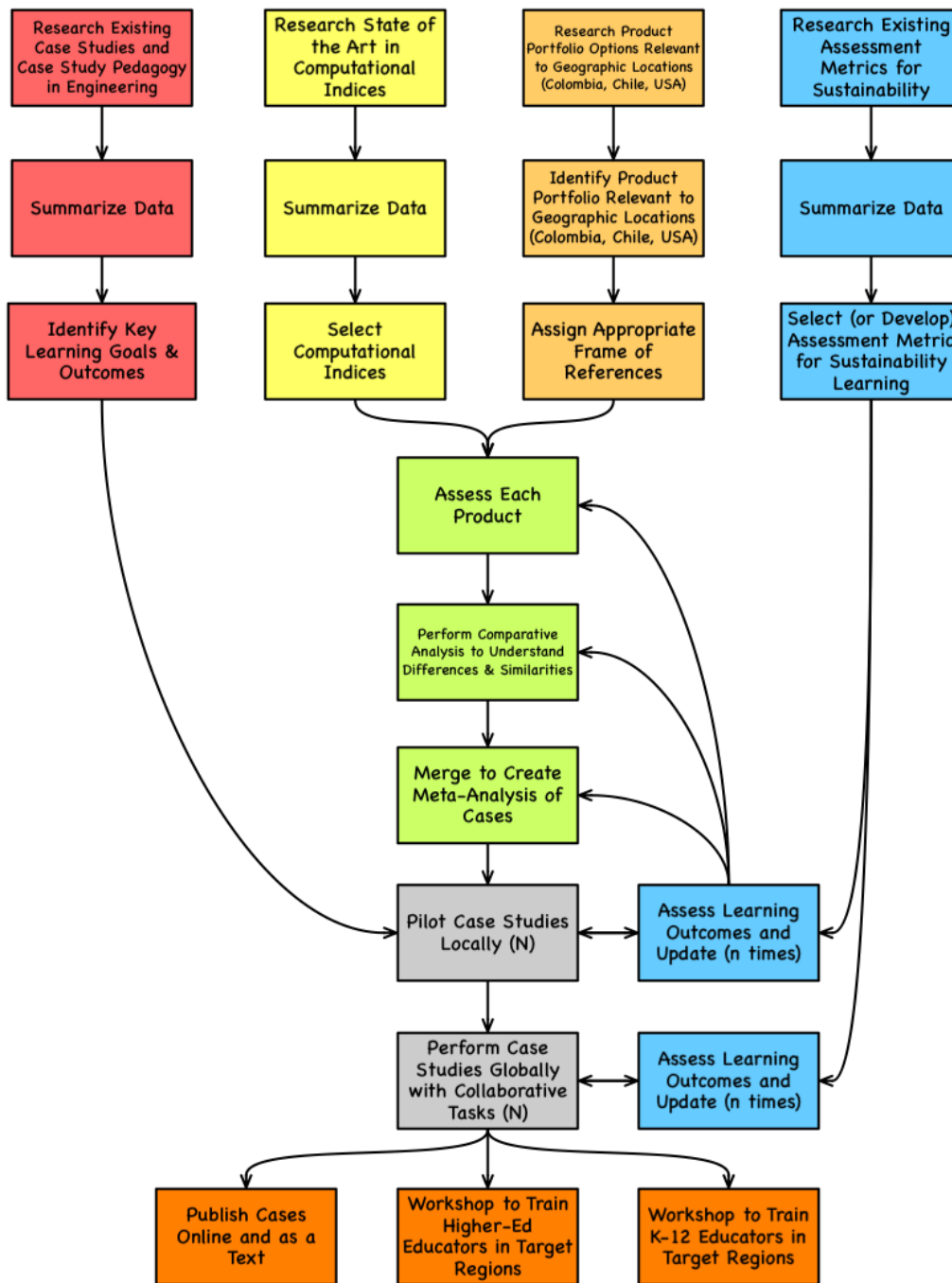


Figure 4: Action plan diagram based on four fundamental components

6. CONCLUSIONS

The proposed project will provide an overall framework that could be easily adopted and adapted by different engineering programs globally. The multinational cooperation in this work will generate discussions and analysis of issues in this field that will contribute to comprehend the different perceptions and understanding of sustainability based on geographical locations and cultural backgrounds. This will promote the development of a pluralism approach to the sensitive issue of sustainability in a global dimension.

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