Grand Challenges in Sustainability: Learning & Integration from Engineering Contexts

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Abstract

The integration of sustainability in leadership training in engineering have largely centered on methods and skills development of the "Green Leader". The National Academy of Engineering has developed a set of Grand Challenges which has sustainability themes embedded into it such as solar energy, carbon sequestration, fusion energy, nitrogen cycle, clean water and urban infrastructure. Graduate education in the sustainability field has not integrated these sustainability themed grand challenges as part of the general graduate sustainability curriculum. Higher education institutions such as Arizona State University have an opportunity to integrate these grand challenges into "Introduction to Sustainability" courses. The advantage of integrating a sustainability theme grand challenge is that students start their graduate education by analyzing real world issues that impact stakeholders, sustainability advocates and public constituents. Students will get to explore and examine these issues in a Learning Lab in a semi-structured learning environment guided by a research question and tools to help define the scope of the sustainability themed grand challenge. Students will be expected to present their work to a real-world client and receive feedback to their solutions oriented recommendations.

Why is sustainability important to engineering?

Sustainability is about defining what we expect from our future. Sustainability is not just preserving current resources for future generations but also reimagining our future goals and behaviors as a larger framework for changing or managing the need to use these resources. Engineering is the derived from the Latin word "Ingenium" which is to mean to contrive and to devise. Engineering sits well as a tool to provide solutions to modern sustainability issues and engineers can be developed as effective leaders in the helm of leading change. Engineering based solutions to sustainability issues provide the "how" but need effective and passionate stewardship to rally other leaders, organizations and communities to commit to a change. Sustainability is a lever for engineers to engage stakeholders, organizational champions and external constituents to find a better way to solve complex and challenging problems through shared values, processes and resources.

What are the grand challenges in sustainability?

There are many challenges to sustainability. One paramount challenge is the human factor. Human activity has been identified as the largest source of sustainability challenges. The field of engineering has identified grand challenges that are imperatives to be addressed. Embedded within these challenges are issues that are both engineering and sustainability in nature. Some of challenges involve environmental, ecological imperatives that graduate students can identify and find connections with. One sustainability gap is developing institutional, community and organizational leaders who can lead the change in these sustainability challenges. Presented below are three out of the possible fourteen grand challenges in engineering as defined by the National Academy of Engineering of the National Academies.

Challenge 1- Provide access to clean water[i].

Desert environments such as the Sonoran desert where the large city of Phoenix is settled has water challenges. Phoenix is primarily served by the Salt River Project from the Salt and Verde water sheds and Central Arizona Project canal system which draws from the Colorado River. Engineers have a challenge to make water access viable and sustainable to a continuing growing megapolis in the desert.

Challenge 2- Engineer better medicines[ii].

Pathogens become resistant to therapeutic drugs from natural selection. Drug resistant strains survive to infect the host and can become resistant to multiple kinds of drugs. Novel solutions such as personalized medicine which target the DNA of the pathogen are part of innovative approaches using Synthetic Biology. New drugs that come into the Federal Drug Authority pipeline use the randomized group clinical study which relies heavily on average results from a group to a drug rather than individual results. Engineers currently have tools to make these important discoveries and change the mechanisms of actions of medicinal therapies.
Challenge 3- Restore and improve urban infrastructure.

How does cost economy and sustainability influence the future of transportation systems? Highly urbanized areas such as Hong Kong have one of the highest density of humans living in a small city footprint. They have the challenge of having to move citizens from Point A to Point B in a cost effective manner while conserving land and energy resources and decreasing the carbon footprint of current transportation systems. This challenge is endemic to urban areas around the globe and engineers can tap into a wide wealth of sustainability solutions.
III. Who should lead in discovering and creating solutions?

Sustainability initiatives need champions, rain-makers and lieutenants. Leaders are needed to recognize and guide others in these sustainability imperatives. Solutions are tools that leaders can use to move sustainability imperatives from a challenge to a manageable change. Sustainability champions are usually those in executive and leadership positions who not only provides access to logistics, resources and funding but also provides strategic guidance to the general direction of a sustainability solution. Sustainability rain-makers usually focus on facilitating access to funding for small to medium scale sustainability projects and initiatives. Sustainability lieutenants also help facilitate the operations of a sustainability project and initiative. Engineers have a distinct role of leading change for sustainability practices, programs and communities. Engineers have credentials and experience that adds to their credibility to be advocates and communicators of sustainability initiatives.

How do we get from Point A to Point B?

Education is a key component for identifying engineering based sustainability challenges through such as initiatives as leadership development programs, training in sustainability strategies and participating in a network of like-minded sustainability peers. A sustainable future demands a leader not just immersed in the sustainability issues but also be able to articulate a

new paradigm that addresses sustainability not in silos but as systems based and have interrelated focus.

Putting it all together using Learning Labs

One learning structure to help integrate sustainability, leadership and engineering in one cohesive student experience is the use of Learning Labs. Learning Labs are a two part hands on collaborative learning experience designed for students to apply theories, models and processes into practice and authentic learning projects. Learning labs are designed to be used in a face to face classroom experience and is suitable for introductory courses in graduate engineering curriculums in industrial, environmental and civil engineering.

How do Learning Labs enrich the online learning experience?
- Learning labs promote a richer and engaging student centered learning experience with collaborative activities.

- Students develop learning artifacts which will be housed in their e-portfolio.
- Students create tangible and authentic components for the student's capstone project.
- Students bring in prior knowledge (from other courses) and apply to the current course and promote weaving of learning within inter-disciplinary courses.
- Students bring in work experience and best practices and apply as them as real world context.
- Some learning labs use Harvard Business Case Studies (HBS) case studies which have compelling stories on sustainability and students use these cases as context for applying strategies and processes learned in the four threads.

Sample Learning Lab on Integrating Leadership, Sustainability and Engineering based on *Challenge 3- Restore and improve urban infrastructure.*

Learning Objectives:
At the conclusion of this activity, the student will be able to:

1. Create a mind map to show the elements of a brainstorm that led to a vision statement
2. Prepare a sustainability vision statement for a local government organization

Part A: Mapping a vision statement

The class is tasked to create a 10 year sustainability program for the transportation system for the City of Goodyear, Arizona. Goodyear is a relatively young city with a population of about 50,000 and 40% of the residents are gainfully employed middle class and rate this city high to very high in living satisfaction. This city does not have a Light Rail System like in Phoenix and has a traditional suburban road infrastructure. There is an opportunity to add a Light Rail System and connect it to the downtown cities of Phoenix, Tempe and Mesa areas which are hubs of commerce, Arizona State University and a vast network of residential communities[iii]. Car ridership is high for the City of Goodyear and a limited bus network exists.

The class will act as a consulting group representing various interests: the community, the city of Goodyear and the state of Phoenix. The City of Goodyear has strategic action plan found in this link: http://www.goodyearaz.gov/government/city-manager-s-office/strategic-plan-goals which can be used a starting point.

The class will be divided into three groups to advocate for three sectors: community citizens, city administrators and state officials. The groups will represent the transportation needs, plans and budgets of their representative sector. Using a brainstorming visualization map (suggestion: Power Point Smart Art Graphics) brainstorm the elements of your group's vision statement for the City of Goodyear, Arizona. This vision statement needs to incorporate the needs of the constituents and the strategic plans of the city and state officials. Save your brainstorming map as this will form part of your deliverable. Create a strategic sustainability vision statement (2 to 3 sentences) that will reflect the needs of the City of Goodyear.

Part B: 10 year strategic sustainability plan for transportation systems
Using the vision statement your group has crafted, create a high-level 10 year strategic and sustainable transportation system feasibility plan for the City of Goodyear. You have a budget of $500,000 dollars to develop this feasibility plan. Be sure to address the functional areas outlined in this link: http://www.goodyearaz.gov/government/city-manager-s-office/strategic-plan-goals Here are some examples of vision statements: http://topnonprofits.com/examples/vision-statements/ and http://treegroup.info/topics/sample-vision-statements.pdf.

Deliverables for each group:
1. Brainstorming Visualization Map using PowerPoint Smart Art Graphics: 1 page
2. Vision Statement and a Framework Outline for pursuing a Sustainability Strategic Transportation System Plan: 2 to 3 pages. Please provide a brief narrative explaining your group's vision statement, its components and the rationale behind it. Your high-level plan for a feasibility study should mention the strategy for determining the transportation needs of the community and major components needed to gather these information.

Shown below are examples of vision statements from select organizations. These statements provide a guiding framework for the organization to operate, meet its customer needs and satisfy its stakeholders. Vision statements in transportation must reflect the involvement of the involved stakeholders, various organizational functions and the recognition as an economic driver for the city. The vision statement must be both inclusive and strategic. These vision statement characteristics for the transportation system for the City of Goodyear, Arizona is complex and is thus a great authentic challenge that situates transportation as a sustainability challenge and looking towards engineering for a long-term solution. The final vision statement must be future forward looking, use clear and concise language and convey a positive message[iv].

Examples of vision statements that incorporate sustainability as a guiding framework and serve as model outcomes for this learning process.

Volkswagen[v]

Our strategy pursues a clear objective: By 2018 the Volkswagen Group is to be the world's most successful and fascinating automobile manufacturer – and the leading light when it comes to sustainability.

PepsiCo[vi]

PepsiCo's responsibility is to continually improve all aspects of the world in which we operate – environment, social, economic – creating a better tomorrow than today. Our vision is put into action through programs and a focus on environmental stewardship, activities to benefit society, and a commitment to build shareholder value by making PepsiCo a truly sustainable company.

The city of Bloomington, Indiana[vii] has a robust process for developing a sustainability oriented transportation vision statement. Students can peruse this process to get inspiring ideas on crafting their own vision statement. The link is
http://bloomington.in.gov/media/media/application/pdf/12257.pdf.

Clinton Foundation: To implement sustainable programs that improve access worldwide to investment, opportunity, and lifesaving services now and for future generations[viii].

Arizona State University[ix]. ASU is a comprehensive public research university, measured not by whom we exclude, but rather by whom we include and how they succeed; advancing research and discovery of public value; and assuming fundamental responsibility for the economic, social, cultural and overall health of the communities it serves.

Evaluation Rubric

Group output will be evaluated based on the following rubric metric and will serve as an evaluation milestone rather than a high-stakes benchmark. This tool in intended to help the engineering student improve on their learning process and outcomes.

Rubric for Evaluating Sustainability Vision Statement for a
Strategic Transportation System Plan:

	3 Exemplary	2 Satisfactory	1 Needs Improvement	0 Did not meet criteria
Group Dynamics	All group members participated in crafting a sustainability vision statement.	Majority of group members participated in crafting a sustainability vision statement.	Some of group members participated in crafting a sustainability vision statement.	Sparse participation of group members in crafting a sustainability vision statement.

Involvement of external stakeholders	Sustainability vision statement involves the organization's complete external stakeholders	Sustainability vision statement involves majority of the organization's external stakeholders.	Sustainability vision statement involves parts of the organization's external stakeholders.	Sustainability vision statement excludes the organization's external stakeholders.
Involvement of internal stakeholders	Sustainability vision statement involves the organization's complete functional areas.	Sustainability vision statement involves majority the organization's functional areas.	Sustainability vision statement involves parts of the organization's functional areas.	Sustainability vision statement excludes the organization's functional areas.
Alignment with Organization's Vision-Mission statement	Sustainability vision statement is strategically aligned with organization's Vision-Mission statement.	Sustainability vision statement is aligned with majority of organization's Vision- Mission statement.	Sustainability vision statement is aligned with parts of organization's Vision- Mission statement.	Sustainability vision statement lacks alignment organization's Vision- Mission statement.
Sustainability vision statement mechanics	Sustainability vision statement is free from grammatical and spelling errors.	Sustainability vision statement has some grammatical and spelling errors.	Sustainability vision statement has numerous grammatical and spelling errors.	Sustainability vision statement has deficiencies in grammar and spelling.
Support of feasibility study to Sustainability vision statement	Feasibility study fully strategically supports the Sustainability vision statement.	Feasibility study strategically supports most of the Sustainability vision statement.	Feasibility study strategically supports some of the Sustainability vision statement.	Feasibility study does not support the Sustainability vision statement.

Score

Group Dynamics	Involvement of external stakeholders	Involvement of internal stakeholders	Alignment with Organization's Vision-Mission Statement	Sustainability vision statement mechanics	Support of feasibility study to Sustainability vision statement	TOTAL SCORE: Max of 18 points

Discussion

At the heart of engaging engineering students to frame sustainability challenges in engineering contexts is to provide an authentic context. Lave & Wenger (1990)[x] notes that authentic contexts allows the learner to use their toolbox of knowledge and skills directly into contexts that may ambiguous, fluid in nature and require a deeper understanding of multi-disciplinary systems. An authentic context is designed to encourage the student to "think in new boxes" wherein students recognize that creative thinking still operates in a structured and constrained environment and that new frameworks of thinking still have to work with existing resources, legacy paradigms and stakeholders with multiple interests.

The context is authentic wherein the learning objectives, tasks and expected outcomes are modeled after a real world professional deliverable but dissected and re-crafted in a safe environment without the high-stakes expectations of administrators, constituents and stakeholders. One authentic context considered for this study is the use of a visioning exercise for a small sized city in Arizona. The visioning exercise takes the student into the process of identifying a sustainability challenge in an engineering context. The authentic context has been pre-identified as the 10 year sustainability program for the transportation system for the City of Goodyear, Arizona. The 10 year sustainability program starts with identifying a guiding vision not just to accomplish the goals of this project but also be strategic and inclusive in nature. Providing for the transportation needs of the city is a complex and multi-faceted activity that will involve various city administrators, departments, citizen constituents and state agencies. Transportation also cuts across various organizational functions such as financial, accounting, legal, marketing and communications, engineering and operations, etc. Transportation is a part of the bigger economic engine that supports and sustains the livelihoods of the citizenry, commercial and industrial enterprises and tourism for the city. The inter-play of the involvement of various organizations, organizational functions and the economic backbone of transportation are key components that students to have their minds wrapped around to enable them to craft an inclusive and strategic transportation vision for the City of Goodyear.

Conclusion

The implementation of a "think in new boxes" activity necessitates the instructor encourage students to bring forth fluidic and divergent thinking in crafting their sustainability vision statements. On the other hand, the high-level outline for planning a feasibility study suggests a

more structured approach that aligns with the planning and transportation engineering protocols of the City of Goodyear and the State of Arizona. This can be accomplished with a detailed Internet research to ascertain the "big picture" parameters such as processes, resources and timelines that have to be observed at the onset of planning. The variety of expected deliverables provides the students a wealth of perspectives that they can provide critical feedback on the interplay of sustainability with engineering. Peer feedback provides a reality check to one's proposed framework and at some point a validation that another peer has gone through a similar or dissimilar thinking process that led them to their "A-ha moment". The role of the instructor goes beyond providing the universally accepted truths but that of facilitating collaborative learning, redirecting learning and encouraging students to go beyond their comfort zones and explore the uncomfortable experience of new knowledge.

References:

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