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STEM and Sustainability: Creating Aviation Professional Change Agents

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Introduction

Sustainability is a system of systems and requires a higher level of understanding beyond concepts and principles. Since the UN declared the "Decade for Sustainable Development" (2004-2015), many higher education (HE) institutions have introduced sustainability into their programs and curriculum to develop their student's awareness of sustainability challenges and their economic, social, and environmental responsibilities. Nonetheless, the absence of understanding how sustainability goals and challenges are interrelated in context to all three pillars (environmental, economic, and social) and all relevant stakeholders is missing from many HE programs.

Student knowledge of sustainability varies, yet their engagement towards sustainability is crucial to their future. It does not suffice to learn sustainability concepts; rather, students must understand the relevance to their future career. HE institutions must move beyond book definitions and theories to demonstrate to students the significance of sustainability in their everyday lives. With the evolution of the workforce and the growing needs of the aviation industry, a clear need for concrete sustainability initiatives and actions have emerged. Sustainability in this sense becomes a matter of survival. For this reason, in this chapter, we will attempt to close three gaps in current sustainability studies: Theory vs practice, intention vs behavior, and education vs workplace.

Our purpose is to develop a 'simple' strategy for integrating all three pillars of sustainability into STEM HE programs that create authentic engagement and real buy-in from the students that are then replicated in the workplace. Based on the literature and our own research projects, we will make concrete recommendations on how sustainability could be integrated and address the workforce opportunities and challenges that this entails.

Background

In a conference at a reputable STEM institution in Zurich, two participants started to speak. 'What topic are you presenting?' asked one to the other. 'A paper on sustainability literacy. Did you know that most students, when asked, can only cite environmental examples of sustainability? Isn't that strange? They don't ever think about the other two pillars'.

'That's not strange,' the woman responded, 'we only do environmental sustainability here. We are not a business school; we are not social scientists. Thus, we teach what we know…' Both women walked away from that conversation with a puzzled look on their faces. For one, 'should we be teaching economic and social sustainability in our STEM programs?', for the other, 'how can you only teach one of the pillars without considering the other two?'

While this conversation took place in Zurich, the same conversation could be heard in STEM HE institutions around the world. The idea that STEM focuses on and should focus on the environmental solutions to the world's greatest issues is problematic in itself. For the aviation industry, the emphasis is placed on environmental issues such as emissions and noise pollution, but the solutions to these issues are embedded in wider political, economic, and social frameworks. According to McManners (2016a; 2016b), the aviation industry is one of the most difficult sectors to apply sustainability as stakeholder views are highly polarized. Let's take McManners' (2016a) example of lowering fuel consumption:

One simple solution is to create slower, more efficient air vehicles, comparable to car hybrids. Scientifically and practically, this can be done. It would reduce the emissions and, despite the minor inconvenience of longer travel time, it is the sustainable solution. So why hasn't it been implemented? The STAKEHOLDERS. The fuel for international flights is tax free, so there is little incentive to slow flights when no money is at stake; thus, the aviation industry prefers to safeguard its status quo. Other industries who rely on the aviation industry to deliver their goods are not interested in slowing things down. Passengers are defensive of their right to fly whenever they want. In fact, the only group that seems interested in this solution are the environmentalists who are keen to support alternative models of flying including flying less. Nonetheless, when asked, almost all stakeholders find the idea of sustainable flying to be desirable; they just don't see a need or incentive to act now. What results is a clear lack of ownership or decision-making power from the potential change-makers and the government. The latter is an interesting stakeholder group: Based on electoral cycles, the issues within the aviation industry are so low on the list of priorities that by the time this issue is on the table, someone new has been voted into office and, again, the environmental damage caused by the aviation industry is relegated to its place at the bottom of the priority list.

There is another reason why seemingly simple yet absolutely possible solutions are squelched: The gap between intention/value and behavior/action. Like the stakeholders in the aviation example, students, too, believe that sustainability is important. They are aware that our current lifestyle is based on unsustainable practices that negatively impact the world, but are reluctant to make lifestyle changes for it (Lambrechts et al., 2018) or give up something they enjoy to make is better (McManners, 2016a). Further, students do not want to take ownership for sustainability issues either. They believe it is more important for future generations (Kagawa, 2007). Thus, while students claim to have pro-environmental behaviors at least occasionally, they often follow the example of the university and community in which they are situated (Emanuel & Adams, 2011). If the HE institution and local community show little interest in sustainability, the students are less likely to replicate sustainability principles into their own actions both on campus and later in the workplace. For this reason, addressing sustainability in STEM HE institutions is crucial to preparing conscientious leaders of tomorrow.

Sustainability in STEM HE institutions

STEM can be defined as “authentic science as participants working in the natural world, working towards a problem, exploring information, using technology, utilizing mathematics, analyzing evidence, developing conclusions, refining questions and methods for future use, communicating results, and recording the results and disseminating information for others to use” (Burrows, Lockwood, Borowczak, Janak, & Barber, 2018, p. 2). In engineering, for example, students view ‘holistic’ image of the region and the problem by following these steps. Nonetheless, studies have shown that students do not view sustainability in a holistic manner; rather, they consider environmental issues more often than social or economic (or political or cultural) (Segalas, Ferrer-Balas, & Mulder, 2010; Thurer, Tomasevic, Stevenson, Au, & Huisingh; Zsoka, Szerenyi, Szechy, & Kocsis, 2013). However, STEM studies revolve around solving ill-structured problems or ‘wicked problems’ that are complex and uncertain and where no one answer is correct nor satisfactory for all stakeholders involved.

Creating Change Leaders

To address wicked sustainability problems, HE institutions need to identify the change agents or change leaders in their student body and amongst their faculty. These change agents have an existing penchant and passion for sustainability issues; they do not have to be convinced about the importance of sustainability and could be the catalysts for the earliest steps toward creating a more sustainable HE institution. To ensure a better future, HE institutions must prepare socially responsible citizens (Zoller, 2015) who encourage sustainable business practices in all industries (Ng & Burke, 2010), particularly STEM industries. Mulder et al. (2012) posits that engaged engineers are crucial for our future as they can and should be empowered moral and social agents to make society more sustainable (El-

Zein & Hedemann, 2016; Zskoka et al., 2013). Our future depends on engineering students who design activities to sustain rather than degrade the natural environment and enhance human well-being; engineers who can deal with the societal aspects of the technologies they are creating (Segalas et al., 2010).

Teaching Sustainability

STEM programs in HE should prepare students to work in a global economy through linking what the students experience (Rus & Yasin, 2015) and learn by doing (Miller, 2014). Teaching sustainability can be completed through stand along courses, embedded into existing courses at a program or university level (Seto-Pamies & Papaoikonomou, 2016; Sidiropoulos, 2014; Verhulst & Lambrechts, 2015; Zizka & McGunagle, 2017). New courses which are interdisciplinary and multidisciplinary and include action-based, real world, and work-based contextual environments could be created that offer a collaborative platform for delivery of content and assignments (Clark & Button, 2011; Kennedy & Odell, 2014; Kurland et al., 2010; Mochizuki & Fadeeva, 2010; Muller-Christ et al., 2014; Zizka & McGunagle, 2018). Figure 1 demonstrates some of the ways that sustainability could be introduced into STEM programs both during the studies and beyond, both inside and outside the classroom or campus.

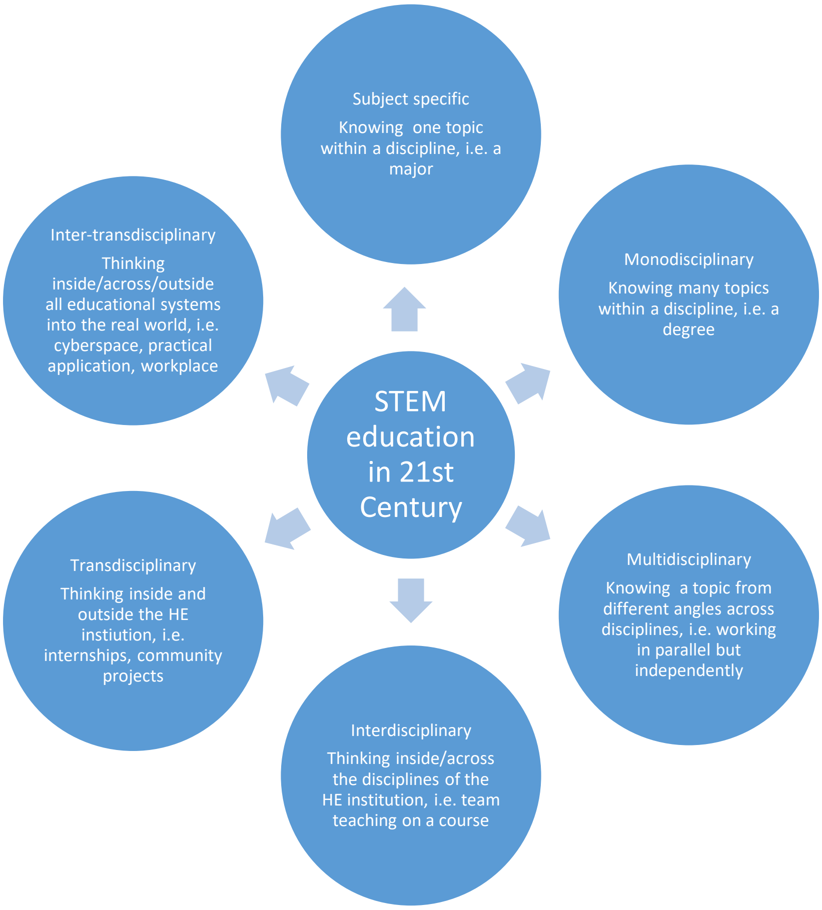

Figure 1. Ways of including sustainability in Stem education in the 21st century.

As seen in Figure 1, the range of options for including sustainability range from subject specific, i.e. one sustainability topic in one specific course and based on one discipline to inter-transdisciplinary which extends beyond the boundaries of a HE institution or campus and occurs after graduation. Aktas (2015) distinguished between *multidisciplinary*, *interdisciplinary*, and *transdisciplinary*: Multidisciplinary entails a weak link and minimal integration between different fields of study where students may work in parallel but are independent of each other; interdisciplinary integrates fields of study which have traditionally been considered as separate entities to solve complex problems that cannot be solved using a mono-disciplinary framework; and transdisciplinary removes disciplinary barriers to form new groups from different fields to solve many problems over an extended period of time. While the latter is more complex, Zoller (2015) added one further option called *inter-transdisciplinary* that is defined as inside and outside that promotes question asking, developing higher order cognitive skills. This option is applicable in non-algorithmic situations and realities and can extend the boundaries of the HE institution itself both physically and in time.

Previous research suggested that STEM programs need to draw from real-life examples in application of concepts outside the classroom which allows the students to make a connection between disciplines, be more responsive, adaptable, creative, and proactive (Egarievwe, 2015; Madden et al., 2013; Prinsely & Baranyai, 2015). Real-life applications of sustainability raise the awareness of how STEM work has on the community and provides the student with engagement between theory and practice.

Zizka, McGunagle, and Clark (2019) found a link in the top 20 STEM HE institutions and the sustainability initiatives they undertook enriched the community as a whole. Leaders in STEM education will be expected to ensure that graduates develop innovative and creative solutions to the world's most complex problems require that sustainability is included within their curriculum, both on and off campus. The top-tier STEM HE institutions did not necessarily offer a stand-alone course or two but required specific actions and initiatives that benefited the communities in which they reside. Sustainability was embedded into their campus and community lives for the students and the community.

Tanggard (2007) discussed the importance to transfer problems across educational context and real world problems. Learning is transformed by the experiences and student participation in the classroom environment. Creating a collaborative platform that allows the student to learn through a multi-level approach. The weekly readings, media, and videos are a great resource to fill in some of the gaps on the material that you may not have fully understood. The assignments can allow the student to conduct research on current sustainability issues and allow them to correlate personal experience with course concepts. Developing a learning environment that offers a rich environment through interaction is essential to the students learning. The engagement through the course activities can provide a robust environment for students.

In the real world, decisions to problems, including sustainability, are often economically driven. Traditional engineering education focused on the response to the needs/demands of employers, industry, and the marketplace. More recently, however, there is a focus on responsibility for decisions that may have a negative impact on society, environment, and resources (Stanikis & Katiliute, 2016). McManners (2016a) suggests a radical new approach for addressing this issue which entails a shift in how the topics are taught in class and how they are adapted in the world. He states, "Instead of seeking to make the most economic case sustainable, make the most sustainable solution economically viable" (p. 87). Simply, what he is suggesting is a different starting place when broaching sustainability. If the bottom line was sustainability and not the typical driver of money; if all decisions and strategies focused around sustainability first and foremost, we have potential for finding better solutions to the world's greatest threats.

Opportunities

The implementation of sustainability into STEM HE institutions' strategy and programs has been long discussed in the literature and many possibilities have surfaced. Sustainability principles can be taught through individual courses, individual speakers/workshops, or individual initiatives, like committees created by students to instigate sustainability changes on campus. But sustainability can also be embedded into several or all courses; it can lead to a certificate, a program, and even a degree. Sustainability can be included in mission and vision statements, as part of the overall strategy, or as an argument to attain an accreditation like ABET that includes sustainability criteria within their evaluation process. Certifications such as AISHE, STARS, or GASU provide an overview of sustainability activities being undertaken on campus though not necessarily in the courses themselves. Yet sustainability is not confined to the campus or courses; rather, it is encouraged outside of the HE institutions through community partnerships, volunteer work, or OUTREACH programs. Most STEM programs engage with the community by hosting these OUTREACH programs to encourage younger students, especially girls, to enter the STEM disciplines. While projects that include the community are a common strategy to increase student engagement, another possibility includes collaboration across disciplines and schools.

Challenges

There are some serious challenges to implementing sustainability or more sustainability into existing programs or institutions. The first is the buy-in. While more than 80% of U.S. universities have courses related to sustainability, the activities vary from adding sustainability into the existing curriculum through a series of lectures for example to making the institution itself more sustainable (Mulder, Segalas, & Ferrer-Balas, 2012). In fact, universities still lag behind corporations and governments in regards to sustainability (Staniskis & Katiliute, 2016) due to lack of money, resources, and other structural conditions (Zsoka et al., 2013). Further, simply 'greening' the curriculum is not a judicious option; it does not lead to greater student engagement or competencies (Segalas et al., 2009) nor does it ensure pro-sustainability behavior outside of school or later in the workplace (Zsoka et al., 2013).

Inspiring Change through Applied Projects

Previous research (Zizka et al., 2019) analyzed 102 community engagement initiatives as the top 20 STEM HE Institutions where all projects fell into the three sustainability initiatives of Environmental, Economic, and Social. The higher percentage of the programs fell into social initiatives followed by economic, and environmental. The community engagement initiatives were both on and off campus. The community engagement involved efforts by the community, students, partners, staff and faculty on both a local and global scale. Zizka et al. (2019) study found that community engagement was one of the most popular projects for the 20 universities was in the form of Outreach that inspired students from K-12 to become the next generation of STEM students. Another community engagement initiative was volunteer service that were both in the local community and abroad. Several of the universities had an Office of Community Engagement that promoted their community partnerships. A unique requirement for all students at Worcester Polytechnic Institute was the requirement to complete an Interactive Qualifying Project (IQP). The IQP expectations was for students to develop a project that provides a solution based on the intersection of science and technology and society.

Many studies examined different types of learning that could be applied to STEM HE institutions when introducing sustainability concepts. Aktas (2015) studied engineering and applied sciences programs have experimented with experiential learning and interdisciplinary studies that consider the three sustainability pillars at the same time as the course content(s). Munakata and Vaidya (2015) investigated project and theme-based learning through a creative science project on sustainability that involved multiple disciplines. In their study, STEM students were paired with art students to complete a collaborative video on sustainability practices.

Another innovative project was initiated at a STEM institution in Lausanne, Switzerland. To encourage all three pillars of sustainability and offer a truly applied project, the scientists from the STEM institution collaborated with two other schools in Lausanne, a business school and an art school. Students were required to work on a multidisciplinary project in teams with a business student and an art student. Each student brought the best of their discipline: The STEM student contributed the rigorous scientific process; the business student ensured the economic feasibility; and the art student added the creative touch. Working in a team, they shared ideas that they wouldn't have otherwise considered. For example, a purely STEM team would have been able to check for scientific flaws or limitations, but not necessarily consider the creative or economic side of the technology or tool they were developing. For Aktas (2015), working in a team of different backgrounds, disciplines, and perspectives leads to better results and more effective solutions that align with the three sustainability pillars and bring added value to the student learning experience.

Table 1

Incorporating Sustainability in STEM HE Institutions on all Levels

Levels	Definition	Example
Subject specific	Investigate a sustainability topic directly related to subject area	Read an article on a sustainability topic related to the course
Monodisciplinary	Investigate a sustainability topic as linked to a specific discipline	Prepare a presentation on a sustainability topic within the discipline
Multidisciplinary	Investigate a sustainability topic from various angles, but independent of each other	Write a report about a sustainability concept using concepts from other disciplines, but not working with them.
Interdisciplinary	Investigate a sustainability topic within the discipline and across disciplines in team effort	Collaborate on a sustainability project with students in other disciplines.
Transdisciplinary	Investigating a sustainability topic within the classroom and applying it outside the HE institution	Create a sustainability partnership with members of the community.
Inter-transdisciplinary	Applying sustainability concepts learned in HE institution outside of that institution and independently learning more (lifelong learning)	Return as an alumni guest speaker/lecturer to impart knowledge to the next generation of future professionals

STEM Education in 21st Century

To conclude this chapter, we would like to offer our vision of STEM education in the 21st century. Based on the literature, we have created this visual that summarizes the best of all teaching practices and approaches to better prepare the next generation of STEM professionals to become *sustainability thought leaders* for the years to come.

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