Sustainability in STEM Higher Education: Making Social Change Together

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This paper examines the sustainability literacy of one pilot group of Science, Technology, Engineering, and Maths (STEM) students in one U.S. HE institution. Currently, the absence of understanding how sustainability goals and challenges are related is missing from many HE programs. Students took the sustainability literacy test (SULITEST) and showed mixed results in regards to their sustainability literacy. These initial results indicate that sustainability tenets are well ingrained by the students, but not the application of sustainability to their lives. The results presented here provide a first indication of the gaps in sustainability education for STEM students in higher education.

INTRODUCTION

Higher education (HE) has played a significant role in the shaping of future leaders and has evolved from traditional magisterial courses of abstract concepts to student-centered learning, from studying for a degree to producing lifelong learners. The course topics, too, have expanded to include gender studies, digital media, and, over the past few decades, sustainability. Since the United Nations declared 2004-2015 as the Decade for Sustainable Development (Seto-Pamies & Papaoikonomou, 2016; Sidiropoulos, 2014), the US passed the Higher Education Sustainability Act (HESA) and the University for a Sustainable Future, an international initiative which focuses on sustainability and environmental literacy, was created (Seto-Pamies & Papaoikonomou, 2016). Through these initiatives, the attitude toward sustainability has shifted from *doing what is necessary* to *doing well by doing right* (Lourenco, 2013). As a result, many HE institutions have introduced sustainability concepts into the curriculum and as part of the school strategy to better prepare students to become leaders who care about the world they share with others.

Of all of the academic disciplines, one particular area has been identified for its potential to contribute to positive social change through sustainability; that is, Science, Technology, Engineering, and Math (STEM). Over 40 billion USD have been spent on STEM education programs and activities in the US

(Charette, n.d.). According to Hopkinson and James (2010), "the economic and social significance of STEM subjects means that STEM-related subjects are integral to sustainable development and therefore STEM education must be re-oriented to sustainable development" (p. 365). Although STEM careers can contribute to society with innovative solutions for green lifestyles and technology (Hopkinson & James, 2010), it is erroneous to believe that "science and technology alone can provide answers to pressing global concerns" (Steele et al., 2012, p. 123). The question of immediate human needs versus long-term responsibility to the environment is one of the greatest challenges STEM students face today (Nagel et al., 2012; Steele et al., 2012). Thus, sustainability and sustainable choices need to become part of their everyday thinking (Nagel et al., 2012) and adapted to different contexts and often opposing stakeholder needs.

To address sustainability in STEM education, HE institutions must change the way students are taught to promote and provoke a more sustainable mindset. As the "greatest contributors to the formation of their students, forthcoming entrepreneurs, business leaders, managers, and employees" (Gonzalez-Rodriguez et al., 2013, p. 2363), HE institutions need to teach sustainability, live it, and believe in it. Admittedly, culture change requires commitment from the top to foster lasting change. In this paper, we will share the results from the first SULITEST conducted with STEM students in one US aeronautical HE institution to identify the gaps and suggest potential methods to address these gaps at curricular, instrumental, and institutional (and external) levels.

In this developmental paper, we address the following three research questions:

RQ1*: How much do STEM students know about global sustainability?*

RQ2*: How can the gaps in sustainability literacy for STEM students in HE institutions be addressed?*

RQ3*: How can HE institutions encourage STEM student engagement with sustainable practices as a lifelong learning process?*

LITERATURE REVIEW

Stakeholder Theory

A stakeholder is defined as anyone who is or could be impacted by the goals of the enterprise; each with his/her own expectations and ability to influence and be influenced by the choices an organization makes (Kvasnickova Stanislavska et al., 2014). Stakeholder theory focuses on the morals and values of a company and the impact of company's environmental, economic, and social activities on key stakeholders such as customers, suppliers, employees, management, shareholders, community members, and/or other relevant stakeholders (Chile & Black, 2015). While all stakeholders should be considered when making strategic decisions, it is often the shareholders' interests and investments which are considered as one of the primary goals of any company is to generate profits. Nonetheless, companies need to make choices that benefit and create value for a wider range of stakeholders (Lourenco, 2013) and enact changes through effective and responsible leadership to achieve a sustainable economy (Cani, 2015). However, stakeholders may view sustainability as someone else's responsibility. Further, they may consider other people as unwilling to change and the barrier to implementing sustainability initiatives or actions (Ceulemans et al, 2015). Other barriers to sustainable choices include managers and employees who are 'ecologically illiterate' (Cooper et al., 2014) and world leaders who fail to achieve sustainable goal targets (Cani, 2015). This paper addresses the former, i.e. sustainability illiteracy, and how it can be addressed in HE institutions.

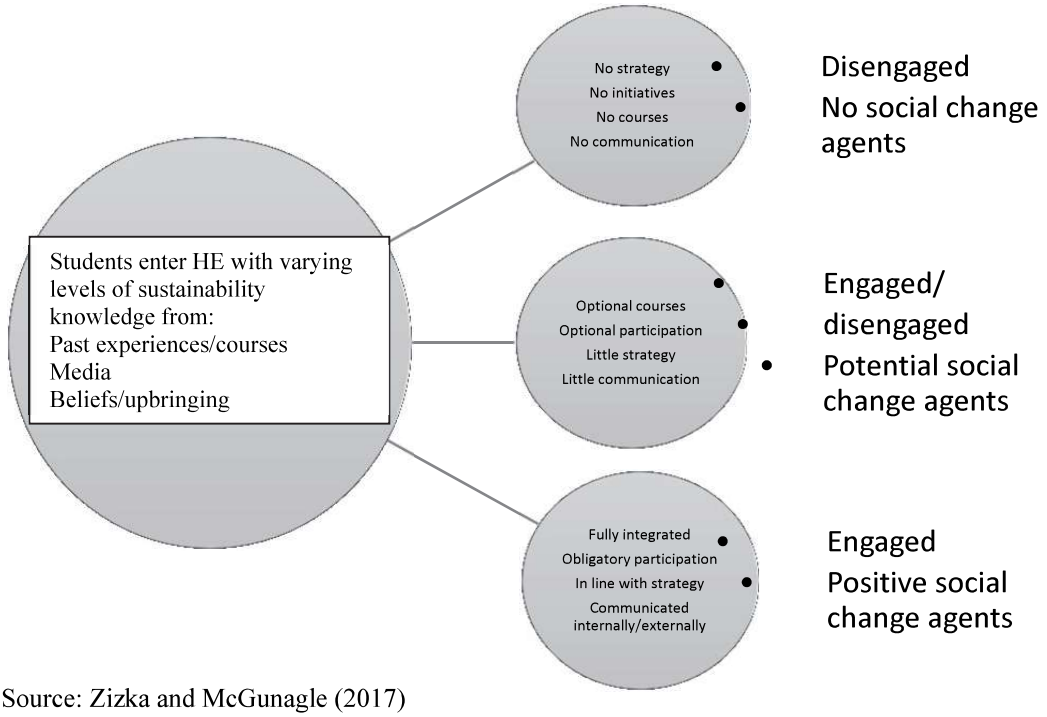
Stakeholder Engagement in HE

In many cases, HE institutions proliferate the traditional top-down philosophy where management makes strategic decisions and everyone else is obliged to implement them. Previous literature has examined the responsibility that management education has to develop sustainable graduates who will

make ethical decisions (Chile & Black, 2015; Lourenco, 2013; Swaim et al., 2014). One way is through active engagement of the key stakeholders (students, staff, governance, and administration), but also of the HE institution itself and its role in the local community (Chile & Black, 2015). HE institutions must be leaders in the community by providing knowledge and educated graduates to deal with sustainability issues (Kurland et al., 2010). To increase engagement in HE institutions, each sustainability initiative must be connected to the core academic purposes of learning and knowledge management (Chile & Black, 2015) or, similar to corporate greenwashing, HE institutions could be accused of *greening curriculum* (Cani, 2015), i.e. misleading students, faculty, or staff that courses have been revamped with more sustainability concepts than actually exist. Failure to make this connection clear may result in cynicism and doubt about their motivations for engagement.

As seen in Figure 1, HE institutions offer varying levels of assimilation and engagement with sustainability in and outside the classroom. Sustainability education varies from stand-alone to embedded courses, single or multidisciplinary focus, obligatory or electives, in or outside the classroom (Seto-Pamies & Papaoikonomou, 2016). Their graduates reflect these different levels of HE engagement in sustainability.

FIGURE 1
SUSTAINABILITY PATH OF HE STUDENT



Source: Zizka and McGunagle (2017)

Students have varying levels of knowledge regarding sustainability and their interest to learn more. For some students, courses which address sustainability issues are regarded positively, but there is no guarantee that the theory would be replicated in a real life situation (Tormo-Carbo et al., 2016). Simply learning about sustainability concepts or being immersed in a sustainability led HE institution does not ensure better practitioners or more ethical professionals. Further, if courses based on sustainability concepts are being forced or true engagement is not sincere from the faculty, staff, or management, students will become skeptical, even cynical, about the sustainability process itself (Gonzalez-Rodriguez et al., 2013) and could not only refuse to engage, but categorically refute any mention of sustainability practices in the future.

Sustainability with STEM Students

STEM education has a fundamental role of advancing technology, medicine, sustainability, agriculture, national security, economy, and society (Egarievwe, 2015). Thus, HE institutions have the responsibility to prepare and inspire the next generation of STEM students through topics such as global awareness, creativity and innovation, critical thinking and problem-solving, communication and collaboration, information-, technology- and media-literacy, leadership, and responsibility (Kennedy & Odell, 2014). According to previous literature, HE institutions are responsible for pursing a sustainable future (Decamps et al., 2017) by preparing students to be 'better' and more sustainably literate managers (Cooper et al., 2014) in the way they address society's socio-economic, political, and environmental issues (Chile & Black, 2015). HE institutions need to create a *green mindset* that follows students into the workplace (Kurland et al., 2010). This begins at HE institutions where students can become change agents (Cooper et al., 2014; Decamps et al., 2017; Kurland et al., 2010; Wiek et al., 2011) or agents of community transformation through social responsibility and sustainability leadership roles (Chile & Black, 2015). According to UNESCO, HE institutions should "contribute to the education of ethical citizens committed to the construction of peace, the defense of human rights and the values of democracy" (Chile & Black, 2015, p. 237) and train future generations of corporate citizens to support and encourage sustainable objectives and initiatives (Bullock & Wilder, 2016; Lourenco, 2013; Moon & Orlitzy, 2011; Weber & Englehart, 2011; Yarime & Tanaka, 2012). Table 1 highlights the opportunities and challenges in implementing sustainability in STEM HE institutions.

TABLE 1
OPPORTUNITIES AND CHALLENGES OF IMPLEMENTING SUSTAINABILITY IN STEM HE INSTITUTIONS

Level	Opportunities	Challenges
Individual	Faculty who are prepared to lead sustainability initiatives are referred to as: *Champions* (Hoover & Harder, 2015; Hopkinson & James, 2010; Verhulst & Lambrechts, 2015) *Change agents* (Mochizuki & Fadeeva, 2010; Seto-Pamie & Papaoikonomou, 2016) *Change leaders* (Kurland et al., 2010); Offers personal satisfaction to those who take on these roles (Hoover & Harder, 2015)	Apathetic/overwhelmed/ no training Not relevant to their discipline (Cooper et al., 2014) Not motivated/personally don't believe (Swaim et al., 2014) No faculty 'buy-in' to sustainability concepts (Nagel et al., 2012) Lack specific training (Lozano et al., 2015) Faculty who are not champions may feel left out (Hoover & Harder, 2015) Involves large amount of time, energy, personal commitment, and supportive environments (Hoover & Harder, 2015)
Individual	Identify and prepare future student *change agents* (Decamps et al., 2017; Kay et al., 2010; Verhulst & Lambrechts, 2015) who have positive attitudes towards sustainability issues (Swaim et al., 2014) and are ready to take on key social issues (Weber & Englehart, 2011) Need to attract student leaders as *agents of community transformation* (Chile & Black, 2015) and *engaged citizens* (Kurland et al., 2010)	Cynical, doubtful, uninterested Students become skeptical if engagement is forced or insincere (Gonzalez-Rodriguez et al., 2013) Students cannot engage if they don't understand the bigger picture in relation to society at large (Cani, 2015) Forcing students to become change agents may result in resentment and resistance to sustainability initiatives (Kay et al., 2010)

Instrumental	Intention Rethink practical experiments in STEM labs such as *Green Chemistry Movement*, replacing current activities with greener materials, conversion processes and products (Hopkinson & James, 2010) Motivating students to engage in sustainable actions in daily life, outside of classroom (Swaim et al., 2014) Students must see themselves as members of the global community (Nagel et al., 2012)	Reality There is a gap between sustainability concerns and daily life in labs and in fieldwork or field trips which have high environmental impacts (Hopkinson & James, 2010) No guarantee that sustainable concepts will be replicated in real life situations (Tormo-Carbo et al., 2016) Must balance traditional objectives like cost with environmental actions (Swaim et al., 2014)
Instrumental	New courses/modules/programs *Ecoversity*: embedding sustainable development into living and learning experience of all students and staff (Hopkinson & James, 2010) Invite civic leaders, governmental reps, community leaders to promote shared learning through sustainable initiatives (Clark & Button, 2011) Create interdisciplinary, multidisciplinary courses with action based and real world and work-based contextual environments (Clark & Button, 2011; Kennedy & Odell, 2014; Kurland et al., 2010; Mochizuki & Fadeeva, 2010; Muller-Christ et al., 2014)	Don't fit in curriculum Course load is full (Cooper et al., 2014) Freeing up someone to lead sustainability initiatives means leaving gaps in core job which someone else must fill (Hoover & Harder, 2015) Legal, political, or social constraints to implementing sustainability into courses or programs (Weber & Englehart, 2011) Professors know their area but not that of others making courses multidisciplinary but without clear connections between disciplines (Kurland et al., 2010) Change is slow in HE settings (Hopkinson & James, 2010)
Institutional	Power Appreciation from university administration and colleagues play a significant role in encouraging faculty to design sustainable curriculum (Muller-Christ et al., 2014)	Power pointing It's someone else's responsibility to teach sustainability (Hoover & Harder, 2015) The 'other' is the barrier to social change, not my discipline or department (Hoover & Harder, 2015)
Institutional and external	Sustainability strategy built with all stakeholders Need for genuine *dialogue* between all stakeholders (Hoover & Harder, 2015; Muller-Christ et al., 2014) and *collaboration* (Kennedy & Odell, 2014) Engaging all stakeholders to promote 'good living campus' (Muller-Christ et al., 2014) Establish a *shared vision* (Hoover & Harder, 2015) where all stakeholders learn from each other (Clark & Button, 2011)	Complex nature and lack of consensus on definitions of sustainability make it difficult to discuss sustainability implementation (Mochizuki & Fadeeva, 2010) Stakeholders might prove territorial and resist change (Hoover & Harder, 2015) External funding is necessary (Verhulst & Lambrechts, 2015) Companies who fund STEM programs want profits and quick results in line with their own agendas (Steele et al., 2012)

Sustainability Tests and Sulitest

The SULITEST enables HE institutions to "assess that they are producing sustainably literate graduates and to engage multiple stakeholders in accelerating the integration of sustainability in higher education standards and beyond" (Decamps et al., 2017, p. 138). The significant role that HE plays in creating a more sustainable world through education, research, and outreach (Yarime & Tanaka, 2012) and producing social responsibility and sustainability literate graduates (Cooper et al., 2014; Yarime & Tanaka, 2012) can be attained through providing graduates with "sufficient knowledge and skills to face global challenges and conduct change toward a sustainable future" (Decamps et al., 2017, p. 139). For this to be successful, a holistic perspective of addressing sustainability in HE is necessary (Decamps et al., 2017) which allows students to examine their ethics and values from a "humanistic perspective" (Weber & Englehart, 2011, p. 566) and understand how global and local sustainability issues matter to everyday living (Kurland et al., 2010).

Previous research has examined other sustainability assessment tools that exist for HE institutions although most assess the institution itself through the forms of voluntary sustainability reporting (Bullock & Wilder, 2016; Ceulemans et al., 2015; Lozano, 2006; Moon & Orlitzy, 2011; Yarime & Tanaka, 2012). Many assessment tools cover only some of the social issues which could lead to suspicion of *greenwashing* which refers to reporting only activities which put the HE institution in a positive light (Bullock & Wilder, 2016). While these assessment tools are useful for advancing the sustainability cause in HE institutions, few assessment indicators examine the skills and knowledge students learn through sustainability education (Yarime & Tanaka, 2012) and are often missing external stakeholders in the reporting process (Ceulemans et al., 2015). For this research project, as we are focusing specifically on HE STEM student knowledge of sustainability, we have chosen to use the SULITEST which assesses students' current knowledge of sustainable development and the roles they will play to create and maintain sustainable changes (Decamps et al., 2017). To our knowledge, little if any research has been published using the SULITEST specifically with STEM students; our project attempts to fill this gap.

METHODOLOGY

Participants were from a fall quarter undergraduate honors level course in a U.S. based university. There were a total of 19 participants that took both the pre and post-SULITEST. The pre-test was administered during the first week of class in the fall quarter. The post-test was given the last week of class for the quarter. The SULITEST is taken on an external platform with results provided to the researcher in an Excel format spreadsheet for analyzation. Table 2 reflects an overview of the topics covered in the SULITEST.

TABLE 2
SULITEST TOPICS

Sulitest Topics	Number of Questions
Core International	30
Knowledge - Sustainable humanity and ecosystems	11
Knowledge - Global and local human-constructed systems	9
Knowledge - Transition towards sustainability	8
Knowledge - Role to play, individual & systemic change	2

As seen on Table 2, the questions are broken down into four knowledge categories for the core international sustainability literacy test. The Core Module of the SULITEST proposes 30 questions randomly selected from the question bank and common to every country, covering global issues and allowing organizations and candidates to compare scores at a worldwide level ('Mapping Awareness',

2017). These question categories are split into themes and subjects which are further divided into 44 specific tags. Tags include questions on basic definitions, specific environmental concerns (climate, pollution, energy, water, etc.), social concerns (human rights, inequality and poverty, discrimination of all sorts, labour practices, etc.), and economic concerns (local and global economic systems, global finance and debt, taxation systems, underground economy, etc.).

RESULTS

RQ1: How much do STEM students know about global sustainability?

In Table 3, we see that the results reflect that the honors class exceeded the country results (U.S.) in all categories of the SULITEST. Furthermore, the honors class met or exceeded the World Benchmark in Core International, Knowledge-Transition towards sustainability, and role to play, individual & systematic change. The areas for improvement to meet the worldwide benchmark would be in the areas of sustainability humanity and ecosystems and global and local human constructed systems. The latter findings could be used to create innovative sustainability courses or activities to encourage authentic engagement with these sustainability tenets.

TABLE 3
PRE-TEST RESULTS

Module / Theme	% Expected	Country Benchmark	Worldwide Benchmark
CORE International	54	46	54
Knowledge - Sustainable humanity and ecosystems	54	49	59
Knowledge - Global and local human-constructed systems	51	45	54
Knowledge - Transition towards sustainability	58	42	50
Knowledge - Role to play, individual & systemic change	55	44	49

Source: SULITEST Pre-Test Fall Quarter 2017

Overall, as seen on Table 3, the results from our pilot group were in line with global results. According to the report "Mapping Awareness of the Global Goals" (2017), 16,575 candidates from 170 universities in 31 countries took the SULITEST between September 2016 and July 2017 and scored an average of 55% of expected answers. Our results scored just below at 54%. Thus, we are in line with the global average for university candidates, but that infers the global average is a goal to attain. In fact, the real goal should be to target raising the global average through the implementation of more effective sustainability courses, initiatives, and projects into HE institutions.

RQ2: How can gaps in the sustainability literacy for STEM students in HE institutions be addressed?

In Table 4, we see the results from fall quarter 2017 where a class of honors students took the SULITEST at the beginning of the class and at the end of the quarter. The results reflect the percentage of increase of the student's knowledge and any decline from the previous test results. The highest increase in knowledge is noted in the democratic institutions at all levels at 49% followed by innovation, creative

leadership and vision of a sustainable way of life at 30%, and climate at 25%. The two areas that experienced the highest decline were formal education and lifelong learning at 28% followed by indicators at 23%.

TABLE 4
GAPS IN SUSTAINABILITY LITERACY

Results per tag Tag	Pre-Test August 2017 % of expected answers	Post-Test December 2017 % of expected answers	% Increase
Basic definitions	50 %	58 %	0.08
Climate	49 %	74 %	0.25
Cultural diversity and heritage preservation	50 %	66 %	0.16
Data and how it is used	63 %	71 %	0.08
Decision making process	50 %	58 %	0.08
Democratic institutions at all levels	25 %	74 %	0.49
Discrimination of all sorts	45 %	54 %	0.09
Energy	35 %	39 %	0.04
Formal education and life-long learning	75 %	47 %	-0.28
Global finance and debt	50 %	37 %	-0.13
Global interdependence and universal responsibility	56 %	60 %	0.04
Indicators	55 %	32 %	-0.23
Inequality and poverty	44 %	63 %	0.19
Innovation, creative leadership, and vision of a sustainable way of life	38 %	68 %	0.3
Interconnected challenges	90 %	76 %	-0.14
International Governance and institutions	73 %	77 %	0.04
Labour practices	57 %	63 %	0.06
Local and global economic systems	66 %	61 %	-0.05
Pollution	58 %	63 %	0.05
Production and consumption systems	64 %	63 %	-0.01
Stakeholder/communities involvement	61 %	61 %	0
Water and sanitation	65 %	68 %	0.03

Source: SULITEST Pre-Post test Fall 2017 Quarter

RQ3: How can HE institutions encourage STEM student engagement with sustainable practices as a lifelong learning process?

Table 3 revealed that students scored above the national average in understanding in all categories of the SULITEST. Conversely, in Table 4, the pre and post-test scores uncover areas where synthesis of application of sustainability beyond the classroom are absent. The lack of synthesis is noted in the areas of interconnected challenges, indicators and formal education and life-long learning. Interpretation of this information indicates that the tenets of sustainability are well ingrained by the students, but not the application of sustainability to the students' lives for the future. Sustainability is a system of systems and requires a higher level of understanding beyond concepts and principles. HE institutions must move

beyond book definitions and theories to explain to students where the worth of sustainability exists as a way of thinking to be practiced every day. The drop in the interconnected challenges and indicators make glaringly obvious the absence of understanding how sustainability goals and challenges are related. Additionally, indicators are measurement of goals and without a firm grasp of how to set or recognize indicators, students will continue to only comprehend the theories of sustainability. To instill sustainable practices as a life-long learning process, HE institutions must generate more tangible based activities such as exploration of relevant industry examples, creation of scenario based learning initiatives and requirement of applied research papers for students. By including these types of activities in the classroom HE institutions will bring theory to practice and assist students with incorporating sustainability into their own lives.

DISCUSSION

Implications of Implementing Sustainability in HE

Based on the integration of sustainability into courses, programs, campus life, and institutional strategy, students graduate from HE institutions in one of the following roles (see Table 5) which summarizes their knowledge of sustainability and their attitude towards it. As seen in this study's results, students at one STEM institution in the U.S. improved their sustainability knowledge in 15 of the 22 criteria, stayed the same in one criteria, and scored lower in six of the criteria according to pre and post-tests in one academic semester. In the pre-test, students scored under 50% for only six criteria (climate, democratic institutions, energy, inequality and poverty, and innovation, creative leadership, and vision of a sustainable way of life) which suggests that they have existing and previous knowledge of sustainability, i.e. are 'aware' of sustainability to various extents. The post-test results demonstrate that this existing knowledge can be improved in the short term, in this case, one semester. Thus, learning about sustainability and improving sustainability knowledge is a feasible endeavor which should be replicated with other students, in other programs, and courses. However, there is no indication in this study that an increase in sustainability knowledge produces a similar increase in engagement. A further study would need to be conducted to establish a correlation between sustainability knowledge and engagement.

TABLE 5
GRADUATING STUDENT ROLES TOWARD SUSTAINABILITY

Aware/Engaged Initiates positive social change Based on knowledge, emotion, strong beliefs, application	**Aware/Apathetic** Refuses positive social change Based on cynicism toward knowledge, negative emotion, strong beliefs
Unaware/Engaged Participates in positive social change Based on emotions, strong beliefs, application	**Unaware/Apathetic** Doesn't know about positive social change Based on lack of knowledge, emotion, and beliefs

Source: Zizka and McGunagle (2017)

As seen on Table 5, if the objective in HE institutions is to graduate global citizens who are aware, engaged, and prepared to make positive contributions in the workplace and in their personal lives, several pertinent questions remain: How can HE institutions ensure authentic engagement between their stakeholders and the greater society as a whole? Do HE institutions really prepare their students for this role? Can HE faculty, staff, and management shift student attitudes, beliefs, and emotions through integrated sustainability? These are questions to be addressed in a future study.

LIMITATIONS

This study had several limitations. Firstly, the sample size of 19 STEM students was small; a larger sample size would need to be examined to confirm our initial findings. The SULITEST could be conducted with different semesters to compare the results. It could also be conducted at the beginning and end of the degree program to gauge the sustainability knowledge attained over time within the HE institution. While this initial pilot study was conducted with STEM students in one U.S. aeronautical HE institution, other STEM students in other HE institutions (inside and outside the U.S.) or other student bodies could be tested as well. Secondly, the SULITEST allowed us to gauge students' knowledge about sustainability, but gave us no indication of where this previous knowledge derived. A future study based on interviews, focus groups, or a survey could be conducted to investigate this question of previous knowledge. Further, the SULITEST does not evaluate students' attitude toward sustainability nor their intentions to replicate sustainability actions in the future. A future research project could include a survey that accompanies the SULITEST where students could rate their attitude and intentions toward sustainability and sustainability initiatives.

CONCLUSION/NEXT STEPS

STEM students are the future change agents in many of the areas where the greatest innovation and potential to help the world face its problems are currently lacking. One industry, the aviation industry, is facing critical situations with keeping aircraft sustainable for the future- personnel, skills/capabilities, supply chain issues, intellectual property, etc. As HE institutions, we have to change the way we instruct if we expect students to take away a more sustainable mindset. We need to teach it, live it and promote it. We know culture change requires commitment from the top to foster lasting change. What we have found with the first pilot SULITEST results has helped to identify the gaps so we can tentatively suggest better methods to address these gaps – case studies, projects, internships. As HE institutions are responsible for producing future change agents, we need to make the transformation to meet the gaps identified in the SULITEST results and ensure our students have a well-rounded understanding of sustainability in the classroom and out in the real world. Our next step is to replicate the SULITEST with a greater sample, both of STEM students and widen it out to test students in other areas as well to confirm what we have found here and to prepare a solid model for teaching sustainability in HE institutions.

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