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Sustainability in Science, Technology, Engineering and Mathematics (STEM) programs: Authentic engagement through a community-based approach

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Abstract:	Higher education Science, Technology, Engineering, and Mathematics (STEM) programs currently offer the theoretical knowledge and industry-related competences that seek to prepare STEM graduates to be leaders to meet 21st century demands. In this research, the authors examined the top 20 STEM Higher Education Institutions (HEIs) in the United States with a goal of establishing any obvious nexus between school reputation, sustainability approaches, and community inclusion. The underlying premise rested in the assumption that schools with the highest STEM program reputation are also the leaders in sustainability initiatives and projects in the respective academic and geographical communities. The findings revealed that on-campus efforts mainly focused on environmental actions, while community engagement projects emphasized the social or economic principles of sustainability. Consequently, the lack of synthesis of projects or initiatives that linked all three tenets of sustainability was the identified gap between what students are learning theoretically in the classroom and the subsequent application in the real world. By making these critical connections, STEM HEIs will produce change agents with a more intrinsic perspective on sustainability rather than one that is gained in a piecemeal manner after they enter their respective professions. By utilizing the tenets of the transformative learning theory, the results from this exploratory study will be employed to create a future model for not only teaching sustainability in STEM programs but, by coupling theory with actions, the results will foster engagement that ensures sustainable development is not an objective but an ingrained mindset that is practiced in daily actions.

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Sustainability in Science, Technology, Engineering and Mathematics Programs: Authentic engagement through a community-based approach

1. Introduction

The United Nations (UN) declared 2004- 2015 the "Decade for Sustainable Development" (Seto-Pamies and Papaoikonomou, 2016; Sidiropoulos, 2014) and introduced the Principles for Responsible Management Education (PRME, 2016) to enhance and extend sustainability into mainstream education (Fernandez-Fernandez and Sanjuan, 2010). According to the UN (2007), "academic institutions have the potential to generate a wave of positive change, thereby helping to ensure a world where both enterprises and societies can flourish". In establishing the PRME, the UN created a voluntary global initiative to enhance and extend sustainability in mainstream education (Seto-Pamies and Papapoikonomou, 2016) to produce change agents capable of initiating sustainability strategies both within the schools and the broader community by engaging all stakeholders in the process (Cooper, Parkes, and Blewitt, 2014). Thus, many Higher Education Institutions (HEIs) have made concerted efforts to shift the focus from merely learning to learning sustainably, which is lifelong learning that will continue after the degree is granted and into the workplace environment. HEIs play a significant role in inculcating students with the "values and skills that contribute to social progress and the advancement of knowledge" (Zeegers and Clark, 2013). Traditionally, management curriculum has focused on making profit whatever the costs (Lozano, Lozano, Mulder, Huisingh, and Waas, 2013); however, this attitude has shifted toward more innovative and sustainable solutions to prepare all HEI students for the real world and the effects they may have on it. One specific area of study that of Science, Technology, Engineering, and Mathematics (STEM) is particularly affected by this shift toward learning sustainably as today's STEM students are potentially tomorrow's global change agents and future leaders in industries worldwide. Each decision they take will have

severe repercussions on society as a whole.

Although the concept of sustainability has been addressed extensively in previous literature, the terms and their definitions vary, often causing confusion and misunderstandings even within the same industry. Sustainability, in general, can be defined as linking the future quality of the global environment (environmental) to potential business opportunities (economic) through innovative and creative solutions which consider all stakeholders (social) (Koc and Durmaz, 2015). Social sustainability "builds on and extends the notion of stakeholder engagement and argues for a better alignment between the physical infrastructure and local conditions and needs" (Keast et al., 2010). This paper places a particular focus on the social sustainability initiatives communicated by the top-ranked STEM institutions and the potential of these initiatives to produce greater stakeholder engagement, especially students, in all three pillars of traditional sustainability. The purpose is to examine the link between sustainability courses taught in STEM HEIs and the real-world application of sustainability in the local community to provide a model to increase student engagement.

STEM education has a fundamental role in advancing technology, medicine, sustainability, agriculture, national security, economy, and society (Egarievwe, 2015). STEM programs prepare the next generation of scientists, tech experts, engineers, and mathematicians to meet 21st century, real-world demands. This new generation will become the future leaders who can manage people and allocate the world's limited resources through innovation, productivity, and social change within a global economy (McGunagle and Zizka, 2018). STEM HEI programs offer the theoretical knowledge and industry-related competences, which should prepare STEM graduates for the work environment and the pertinent global concerns such as sustainability. These programs offer opportunities for STEM students to learn by doing (Millar, 2014), to learn from experience (Rus and Yasin, 2015), to learn how to learn (Appleby et al., 2012) about

their subject areas, but have not necessarily linked this learning to sustainability. STEM programs encourage finding the most viable options to global problems without necessarily considering the most sustainable option. With the power of solving problems in their hands, STEM HEIs need to consider how their solutions will affect the greater world in the long term.

To prepare STEM students to become potential change agents, they must learn to apply their theoretical knowledge to the three pillars of sustainability: Economic, environmental, and social. The literature suggests a link between sustainability principles and corporate reputation, including that of HEIs (Zizka and McGunagle, 2017; Zizka, McGunagle, and Clark, 2018), but these are based on the inference that doing well will boost the school's reputation. To date, there is no evidence that this is the case. Sustainability is, undoubtedly, an essential topic that all HEIs address, yet most of the literature focuses on how to embed sustainability into existing programs rather than how to link sustainability with reputation. Further, scant literature has been found linking top-ranked STEM HEIs and their sustainability actions/initiatives in the local community with reputation. This study aims to fill this gap by examining the sustainability initiatives that are communicated to all stakeholders via the school's official website. The premise is that STEM HEIs with the highest reputation rankings will be the change leaders in effectively engaging with sustainability principles both on and off-campus. With reputation comes responsibility; these top-ranked STEM HEIs should be the thought-leaders and change agents in addressing the global issue of sustainability both in the present and for the future. In this study, the top 20 STEM HEIs ranked by Forbes, 2016, will be examined through their sustainability curriculum, practices, and projects. The assumption is that STEM HEIs will have strong ties with the community when choosing and promoting their sustainability initiatives.

To attain accreditation and, subsequently, increase reputation, HEIs have turned

toward community engagement through outreach programs from the university to the community, service projects, and community-based research (Franz, Childers, and Sanderlin, 2012). According to the Carnegie Foundation for the Advancement of Teaching (2015), engagement is defined as "the collaboration between institutions of higher education and their larger communities (local or global) for the mutually beneficial exchange of knowledge and resources in a context of partnership and reciprocity" (Gorski, Obeysekare, Yarnal, and Mehta, 2015). This engagement involves students who commit time and energy at varying levels, and, subsequently, reap the rewards of their engagement (Ryan, 2017). HEIs have begun focusing on social change, reflection on sustainability issues, and pressing global problems through community-based and engaged scholarship initiatives (Engle and Halsell, 2017). They now need the recognition and resources to develop these initiatives further, which is one area of contention for STEM programs.

This study starts by asking the question, how can greater stakeholder inclusion lead to authentic engagement in sustainability initiatives and actions to produce change agents and change leaders? To answer this question, we examine the link between sustainability courses taught in STEM institutions and the applications of sustainability in the local community that could create a model to increase authentic student engagement. A content analysis of 20 Top University websites was conducted to answer the research questions on implementing, sustainability into their academic programs, communicating sustainability initiatives/actions to the stakeholders, and the sustainability initiatives reflected in their mission and vision statements.

This paper is organized in the following manner: Section 2 includes a review of the literature on sustainability in higher education, both the opportunities and challenges associated with it. In Section 3, the methodology is summarized, followed by Section 4, which presents the results focusing on accreditations and sustainability initiatives

undertaken by the top-rated STEM schools. Section 5 includes a discussion on what the results mean in regards to university reputation. Section 6 offers conclusions and implications for the future of sustainability in STEM and other relevant academic programs.

2. Literature Review

2.1. Sustainability in HEIs

Over the past few decades, HEIs have become significant contributors to the promotion of sustainability as a field of study and a strategic mindset (Karatzoglou, 2013). In 2007, the United Nations stated that "academic institutions have the potential to generate a wave of positive change, thereby helping to ensure a world where both enterprises and societies can flourish" (Seto-Pamies and Papoikonomou, 2016). HEIs should aim to produce responsible graduates who "do better things" and "see things differently" than the generations before them (Sidiropolous, 2014).

Sustainability can be implemented into existing courses and programs in HEIs numerous ways from a stand-alone mandatory course, electives, embedded into one, several, or all courses, at a program level, or on an institutional level (Jones Christensen, Peirce, Harman, Hoffman, and Carrier, 2007; Seto-Pamies and Papaoikonomou, 2016; Sidiropoulos, 2014; Verhulst and Lambrechts, 2015; Zizka and McGunagle, 2017). New courses which are interdisciplinary and multidisciplinary and include action-based, real-world, and work-based contextual environments could be created (Clark and Button, 2011; Kennedy and Odell, 2014; Kurland et al., 2010; Mochizuki and Fadeeva, 2010; Muller-Christ et al., 2014; Zizka and McGunagle, 2018). Sustainability actions can be initiated by student-led changes, campus operations, or as part of the HEI strategy (Verhulst and Lambrechts, 2015).

As part of the strategy, HEIs seek recognition through external accreditation. Accreditation and rating systems influence what is taught within a HEI and how it is

implemented. One prestigious accreditation, Association to Advance Collegiate Schools for Business (AACSB), focuses on "continuous quality improvement in management education through engagement, innovation, and impact" (AACSB, 2016). AACSB posits that "society is increasingly demanding that companies become more accountable for their actions, exhibit a greater sense of social responsibility, and embrace more sustainable practices" (AACSB, 2016,). They believe that a school's prestige is "significantly and positively associated with offering more CSR and sustainability education" (Nicholls, Hair, Ragland, and Schimmel, 2013). Another U.S. accreditation is New England Association of Schools and Colleges (NEASC). According to their criteria, graduates successfully completing an undergraduate program "demonstrate knowledge and understanding of scientific, historical, and social phenomena, and a knowledge and appreciation of the aesthetic and ethical dimensions of humankind" ("Standards", 2016). For the Middle States Commission on Higher Education accreditation, the motto is, "Our students are well-served; society is well-served" (MSCHE, 2015). Further, accreditations exist that are specifically geared toward STEM students and HE institutions. One such example is the Accreditation Board for Engineering and Technology, Inc. (ABET) that offers 'proof' that a collegiate program (s) has met the standards to prepare STEM graduates for leadership roles in the workplace through innovation, emerging technologies, and respecting the welfare and safety of the greater community (www.abet.org),. ABET accreditation cites two specific criteria for sustainability: "1) Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare as well as global, cultural, social, environmental, and economic factors; and 2) recognize ethical and professional responsibilities in engineering situations and make informed judgments considering the global context" (Thurer, Tomasevic, Stevenson, Au, and Huisingh, 2018).

Much literature focused on the importance of establishing student and faculty

'change agents' who will make informed judgements regarding the global context and lead by example for the other students and faculty (Decamps et al., 2017; El-Zein and Hedemann, 2016; Gonzalez-Rodriguez et al., 2013; Lozano and Lozano, 2014; Lozano et al., 2015; Matten and Moon, 2004; Mochizuki and Fadeeva, 2010; Seto-Pamies and Papaoikonomou, 2016; Verhulst and Lambrechts, 2015; Zizka and McGunagle, 2018; Zsoka, Szerenyi, Szechy, and Kocsis, 2013). These initial change agents are identified as those who have a passion for sustainability (naturally or from previous experience). They are prepared to become 'ambassadors' (Verhulst and Lambrechts, 2015), 'change leaders' (Kurland et al., 2010; Staniskis and Katiliute, 2016), 'citizen managers' (Gonzalez-Rodriguez et al., 2013) 'corporate change agents' (Hesselbarth and Schaltegger, 2014; Lambrechts, Ghijsen, Jacques, Walravens, Van Liederkerke, and Van Petegam, 2018) or 'champions' (Hoover and Harder, 2015; Hopkinson and James, 2010; Verhulst and Lambrechts, 2015) for the sustainability cause.

These change agents do not need to be convinced about the importance of sustainability in HEIs; instead, they encourage others to follow. However, some stakeholders might prove territorial or resistant to change (Hoover and Harder, 2015), making acceptance of sustainability initiatives complex and slow. Further, as HEIs are notoriously known for being slow to change (Hopkinson and James, 2010), finding solutions for implementing sustainability into HEIs could potentially be a long and frustrating process.

Despite the potential benefits of implementing sustainability into HEIs, there are many constraints or challenges as well. Verhulst and Lambrechts (2015) identified four primary areas of contention when trying to implement sustainability into HEIs. These include resistance (a threat to their interests or status quo), communication (lack of shared understanding or common knowledge), empowerment and involvement (the belief that the group can perform essential and valuable tasks well), and organizational culture

(shared underlying assumptions). These areas of contention are affected by a lack of support, resources, ability/knowledge, motivation, and recognition (Lozano and Lozano, 2014; Lambrechts et al., 2018; Verhulst and Lambrechts, 2015). Other challenges cited included organizational factors such as apathy (Cooper et al., 2014), inadequate financial resources, low appreciation of outreach activities (Hoover and Harder, 2015; Karatzoglou, 2013), lack of space in the program or curriculum (Lozano and Lozano, 2014; Mulder, Segalas, and Ferrer-Balas, 2012; Nicolls et al., 2013), isolation and low self-confidence (Lozano et al., 2013), and perceived relevance or consistency when implementing sustainability into academic programs (Deale and Barber, 2012; Drayson, Bone, Agombar, and Kemp, 2014). Faculty may be resistant to introducing sustainability into their courses if it is perceived as an additional responsibility to be added to an already packed course load (Cooper et al., 2014; Zizka and McGunagle, 2018). Further, faculty may struggle with finding clear connections and links between their course material and sustainability concepts (Kurland et al., 2010) or differing opinions on definitions of sustainability between colleagues (Mochizuki and Fadeeva, 2010). Some professors may even believe that it is someone else's responsibility to teach sustainability and that the 'other' is the barrier to social change (Hoover and Harder, 2015). For this reason, faculty need encouragement from HEIs' administration and colleagues when designing and implementing sustainability in their courses.

2.1.1. Student perceptions

Previous literature has examined how HEIs contribute to sustainable development through research and knowledge generation (Lozano et al., 2015), access to transferable knowledge and skills on sustainability which could be applied in the future (Seto-Pamies and Papaoikonomou, 2016), and changes in everyday operations to reduce the environmental impact and increase the positive social impact (Lozano et al., 2015). Implementing sustainability in HEIs involves collaboration and increased

interaction of different stakeholders (Othman and Othman, 2014; Seto-Pamies and Papaoikonomou, 2016) throughout the campus and in the greater community (Gonzalez-Rodriguez et al., 2013) to encourage authentic engagement through real-life application of sustainable practices (Sidiropoulos, 2014), genuine dialogue (Hoover and Harder, 2015; Muller-Christ et al., 2014), and a shared vision of how the world could be (Hoover and Harder, 2015). These connections between stakeholders are crucial when attempting to shift student attitudes toward more sustainable choices in the future.

Past studies have examined the specificities of Millennials both in education and the workplace. Millennials have been described as self-indulgent and greedy (Twenge, 2010), entitled (Kitterlin, 2015; Levenson, 2010; Ng, Schweitzer, and Lyons, 2010), narcissistic (Costanza and Finkelstein, 2015; Kitterlin, 2015). Nonetheless, these same Millennials are civic-minded (Kitterlin, 2015; Kowske, Rasche, and Wiley, 2010; Myers and Sadaghiani, 2010) and search for opportunities to make a difference in education and the workplace (Kowske et al., 2010). In general, STEM HEIs, filled with Millennial STEM students, have a fundamental role in advancing technology, medicine, sustainability, agriculture, national security, economy, and society (Egarievwe, 2015). STEM students are critical protagonists for making society more sustainable (Lozano and Lozano, 2014; Mulder et al., 2012; Zsoka et al., 2013).

Previous studies also examined student perceptions of sustainability in the HEI curriculum and found that, overall, students think learning about sustainability is a ‘good thing’ but more important for future generations (Kagawa, 2007). Students reported being concerned about the wasteful consumption of natural resources and agreed that the world’s economy is based on unsustainable practices that have adverse effects (Emanuel and Adams, 2011). Nonetheless, students admitted to having a minimal understanding of sustainability (Lambrechts et al., 2018) and little time to learn more. They raised concerns about an overload in the coursework (Cooper et al., 2014; Stir, 2006). Some

students have posited that sustainability is not their responsibility, and their actions will not make a difference (Chaplin and Wyton, 2014; Hoover and Harder, 2015). They do not see the point in learning about these concepts in HEIs or engaging in sustainability actions (Cani, 2015). Thus, it is essential to introduce socially responsible activities that are linked to the studies, interests, and causes which affect the students most.

Students become skeptical if engagement is forced or insincere (Gonzalez-Rodriguez et al., 2013), and forcing students to become change agents may result in resentment and resistance to sustainability initiatives (Kay, Dunne, and Hutchinson, 2010). While students may be initially motivated to engage with sustainable actions, 'token' gestures, often referred to as 'light green activities' which are too simplistic or actions that require too much effort, will be dismissed. Students will choose a more comfortable option that will not impinge on their lifestyle (Chaplin and Wyton, 2014; Kagawa, 2007; Zsokas et al., 2013). This option is often referred to as the 'rhetoric-behavior gap' (Kopnina and Meijers, 2013), or the 'value-action gap' (Lambrechts et al., 2018), i.e., the large gap between students' knowledge of sustainability issues, the values they attach to them, and their motivation to behave in sustainable ways. According to Stir (2006), students will not change behavior by abstractly or theoretically learning about sustainability issues; instead, they need to analyze and investigate real-world problems to solve them strategically. For this reason, HEIs need to find ways to engage students in authentic sustainability initiatives and actions which show immediate and clear evidence that actions, no matter how insignificant, affect the larger society as a whole.

2.2. HEIs and Community Engagement

According to Rundle-Theile and Wymer (2010), "universities owe society graduates who are ethically responsible. Graduates need to understand they have responsibilities not only to themselves and their companies but also to other important

societal stakeholders". Students in HEIs must learn that successful leaders must prioritize the interests of people (Giacalone and Thompson, 2006). HEIs can and must transform societies by educating decision-makers, leaders, entrepreneurs, and academics to serve the greater public good (Lozano et al., 2013). To do so, HEIs need to view sustainability issues and practices as embedded in the local economy and community (Karatzoglou, 2013) and holistic by serving all three pillars of sustainability (environmental, economic, and social) (Karatzoglou, 2013; Nicholls et al., 2013), within and across courses (Lozano et al., 2013; Zeegers and Clark, 2013), in classes, and on and off-campus (Chaplin and Wyton, 2014). For Lozano, Lukman, Lozano, Huisingh, and Lambrechts (2013), sustainability should be the 'golden thread' throughout the entire university system.

Previous literature has addressed the need of HEI students to become aware of the larger society and their issues through public service, civic engagement, service-learning, community service, volunteerism, or community outreach programs (Schatteman, 2014). However, there are specific challenges for each of the stakeholder groups involved in community engagement initiatives. For the community stakeholders, one problem is the balance of power between HEIs and the community (Gorski et al., 2015; Sandmann and Kliewer, 2012). Other community challenges included the academic schedule which may not coincide with the community's timeline, the difficulty in liaising with the 'right' person at the HEI, or the disagreement on the type of knowledge which should derive from the project (Sandmann and Kliewer, 2012). For student stakeholders, challenges can lead to unintended consequences such as becoming disillusioned, gaining a skewed perspective, or leaving a project unfinished, which, subsequently, leaves a community disappointed and disillusioned (Gorski et al., 2015). Some students do not feel connected to the project or feel they abandoned those being served (Ryan, 2017). Finally, for faculty, the challenges derived from not knowing how to get HEI 'buy-in', difficulty in recruiting students/volunteers, or lack of desire, time,

and experience to directly engage with the community (Mehta, Gorski, Liu, Weinstein, Brua, and Christensen, 2015).

Despite these challenges, the literature has also shown positive opportunities between HE institutions and the greater community. The community witnesses the implementation of projects with actionable knowledge plans (Gorski et al., 2015), and the HEI improves its reputation (Franz, Childer, and Sanderlin, 2012). For faculty, community engagement projects offer pedagogical strategies to improve teaching and learning (Franz et al., 2012; Ryan, 2017; Segalas, Ferrer-Balas, and Mulder, 2010) as students' interest and emotions are aroused (Mehta et al., 2015). Faculty can also profit from research and publication opportunities from these projects (Gorski et al., 2015). For students, the learning tasks are connected to real-world applications, which makes them authentic (Thompson and Davis, 2013) and more attractive. Previous research found that students were highly motivated to help others and were enthusiastic toward making a positive difference in their community (Gorski et al., 2015; Schatteman, 2014). Thus, from the literature, it is clear that authentic engagement between the stakeholders in HEIs and the community can lead to further opportunities for more positive community engagement initiatives and more positive social change.

2.3. Sustainability in STEM HEIs

The literature has examined the importance of STEM education to address pressing global concerns, but the emphasis has remained predominantly on wealth generation to guarantee future economic prosperity in a completive global market (El-Zein and Hedemann, 2016; Panizzon et al., 2014; Steele, Brew, and Beatty, 2012). As companies who fund STEM programs want profits and quick results in line with their agendas (Steele et al., 2012), STEM HE institutions struggle with balancing traditional objectives like cost with environmental actions (Swaim et al., 2014). While much of the funding for STEM education derives from corporate funding with their specific agendas

and concerns and the focus is on profit-making, Steele et al. (2012) suggested a balance between science and technology on the one hand with social and environmental concerns on the other to address present and future sustainability. However, with a shortage of STEM graduates (Charette, n.d.), there is a need for training and learning programs which focus on innovation-led growth and successful partnerships (Prinsley and Baranyai, 2015b) and prepare students to make better decisions for the future (Steele et al., 2012).

While STEM education prepares students for specific disciplines within science, technology, engineering, and mathematics, there are clear overlaps between these fields. For example, engineers solve problems through the implementation of technology and the use of resources (El-Zein and Hedemann, 2016; Mulder et al., 2012); thus, engineering and technology are intertwined in STEM studies. Engineers face wicked problems that are complex and uncertain by designing activities to sustain rather than degrade the natural environment while considering the public good (El-Zein and Hedemann, 2016; Lambrechts et al., 2018; Mulder et al., 2012; Segalas, Ferrer-Balas, and Mulder, 2010). Engineering courses must be interdisciplinary, multidimensional, problem-based, and integrated (Mulder et al., 2012; Staniskis and Katiliute, 2016) to produce future-engaged engineering change agents.

In traditional STEM education, there exists a gap between sustainability concepts taught in the classroom and daily life in labs and in fieldwork, which have high environmental impacts (Hopkinson and James, 2010). However, some initiatives, such as the Green Chemistry Movement, have been developed to replace current activities with greener materials, conversion processes, and products (Hopkinson and James, 2010). Nonetheless, there is no guarantee that sustainable concepts will be replicated in real-life situations (Tormo-Carbo et al., 2016) unless students are motivated to engage in sustainable actions in and outside the classroom (Swaim et al., 2014) as members of the

global community (Nagel et al., 2012). To stimulate engagement with sustainable concepts, STEM HEIs have encouraged STEM faculty to use real-life examples in the application of STEM concepts outside of the classroom. STEM students need to make connections between disciplines (Egarievwe, 2015; Madden et al., 2013) to be more responsive, adaptable, creative, and proactive (Anajar, Talbi, Radid, Snadrou, and Tragh, 2015; Prinsely and Baranyai, 2015a). As employers seek employees who have life skills and experience beyond their academic knowledge (Applyby, Roberts, Barnes, Qualter, and Tariq, 2012), teaching sustainability concepts based on authentic experiences and conditions could be a positive initial step. The real-life application raises awareness of the impacts that STEM work can have on the larger community and ensures student engagement between theory and practice, particularly for a topic such as sustainability.

Based on the previous literature and the gaps discovered in the search, this paper aims to demonstrate a link between sustainability initiatives in top-ranked STEM HE institutions' academic programs and increased community engagement (both on and off-campus) involving all of the stakeholders. The overall purpose is to explore how greater stakeholder inclusion can lead to authentic engagement with sustainability initiatives and actions to produce change agents (in the short term) and change leaders (in the future workplace).

To examine this topic further, the following research questions will be addressed:

RQ 1: How do top tier STEM HEIs implement sustainability into their academic programs?

RQ 2: How are top tier STEM HEIs communicating their sustainability initiatives/actions to the stakeholders?

RQ3: How are sustainability initiatives and community engagement of top tier STEM HEIs reflected in their mission and vision statements?

3 Methodology

This study starts by asking the question, how can greater stakeholder inclusion lead to authentic engagement in sustainability initiatives and actions to produce change agents and change leaders? To answer the research questions empirically, this study used an exploratory approach that relies on content analysis methodology. Utilizing an exploratory approach, the content analysis of existing website information was used as it was the most observable communication channel for promoting sustainability initiatives and actions to their stakeholders. The use of an exploratory design also allowed the researchers to create the groundwork for future research that will shape more conclusive findings.

A qualitative content analysis method was adopted to suit the unique needs of the research questions (Cozby and Bates, 2012; Mayring, 2014). This method is suitable when the research objectives can be answered through analysis of communication, in this case through website data, and selection of the appropriate units for analysis for the research, i.e. college mission and vision statements, accreditations and sustainability initiatives (Williamson, Given, and Schifleet, 2018). STEM universities and their programs need to be accredited by the appropriate accreditation agency. Accreditation of a STEM program ensures that a graduate is better prepared to enter the STEM field in the global economy.

To better define the content analysis method, a judgement sampling was employed as a non-probability sample of HEIs that are most representative of the sample population as a whole (Crowther and Lauesen, 2019). Guthrie and Abeysekera's (2006) research discussed content analysis (CA) as a technique that can be used for gathering data that creates a procedure that can make valid inferences from text that involves coding qualitative and quantitative data into pre-defined categories in order to derive patterns. Steenkamp and Northcott's (2007) mechanistic approach stated the larger the

amount of data the greater the importance to a particular topic. Content Analysis utilizes a unit of scrutiny to record elements which refers to words, sentences, paragraphs and portions of pages on the topic. The second approach is meaning orientated method that provides an in-depth analysis. The method attempts to understand the content and concept of what is being analyzed. The implication is there is more concern for the quality, richness, or qualitative content of the narrative (Unerman, 2000; Beck et al, 2002). This study utilizes the second approach, were the data was analyzed using NVivo for themes that provide meaning from the content. A score of 1 was given if the disclosure revealed a description or narrative in the content. All data was qualitative with no monetary value or diagrams.

Content Analysis is a widely used method of transferring qualitative data to quantitative that can be further examined. Krippendorff (2004) supported the meaning of Content Analysis as a technique for making replicable and valid inferences from texts to contexts of their use. The scoring process is undertaken through the use of a guideline interpretation. The interpretation is important when conducting the analysis in measuring qualitative data. An in-depth analysis was conducted on the websites, academic programs, mission and vision statements.

To further define the research context, the top 20 U.S. STEM HEIs were examined to gain insight into the institution sustainability curriculum, practices, and projects to establish any apparent links between school reputation, sustainability, and community inclusion. The analysis of the content found on the official university websites can be justified for three reasons: 1) written documents have accurate and exact information which has been verified before publication online; 2) written records on public websites ensure an unobtrusive way to obtain and assess data unlike the more obtrusive way of soliciting individuals for comments; and 3) written documents represent HEI's overall attitude, culture, and engagement with relevant real-world issues

(Franz et al., 2012).

The top 20 STEM US HE institutions employed are listed in Table 1. The rankings are derived from Forbes. According to Forbes' official website (https://www.forbes.com/sites), careers in technology continue to rise in number and pay – four of the majors with the highest hiring rate for recent grads are in STEM; thus, these STEM HEIs are becoming better investments of tuition dollars. To be considered a STEM school, the most popular areas of study included at least 40% in STEM, according to the Department of Education's College Scorecard (Coudrier, 2016).

Table 1

Top 20 U.S. STEM Schools

School ranking
1. Massachusetts Institute of Technology
2. United States Naval Academy
3. Cornell University
4. Rice University
5. United States Air Force Academy
6. California Institute of Technology
7. Harvey Mudd College
8. Carnegie Mellon University
9. Johns Hopkins University
10. Georgia Institute of Technology
11. Cooper Union
12. Case Western Reserve University
13. United States Coast Guard Academy
14. Rensselaer Polytechnic Institute
15. Colorado School of Mines
16. Worcester Polytechnic Institute
17. California Polytechnic State University, San Luis Obispo
18. University of Portland
19. Rose-Hulman Institute of Technology
20. North Carolina State University, Raleigh

Source: https://www.forbes.com/sites/cartercoudriet/2016/07/07/top-stem-colleges-of-2016/#70c521195ba8

With the sample set identified, the qualitative content analysis directed or deductive method was employed through the creation of categories for sustainability initiatives and actions to their stakeholders (Mayring 2014). In RQ 1, the main element

was identification of implementation of sustainability into academic programs (Mulder et al, 2012; Staniskis and Katiliute, 2016; Thurer et al, 2018; Lozano and Lozano, 2014). In RQ 2, the research examined the ways of communicating initiatives to stakeholders (Franz, Childers and Sanderlin, 2012; Ryan, 2017; Engle and Habsell, 2017). In RQ 3 the researchers compared the mention of a sustainability strategy in their vision and vision statements across HEIs (Staniskis and Katiliute, 2016; El-Zein and Hedemann, 2016; Lozano and Loranzo, 2014). Figure 1 provides a summary of steps applied in our methodology.

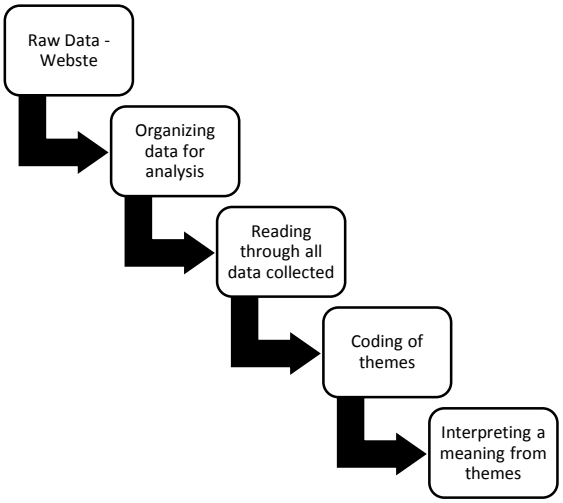

Fig. 1. Summary of Steps used in Methodology Approach

3.1 Data Collection

Researchers achieve credibility with evidence of identifiable conditions, such as (a) triangulation of data and methods, (b) peer review of coding, categorizing, and theorizing of results, and (c) peer debriefing and sharing developing analysis with a peer. The procedures for the current study involved gathering and coding data from websites and written documents. A spreadsheet was used for categorizing and coding to evaluate the qualitative data. The researchers analyzed the data from official websites, using keywords to review their sustainability initiatives, actions, clubs, community engagement, accreditation, mission & vision statements that supported Table 2

Accreditation for Top 20 STEM schools and Table 3 Sustainability Initiatives On-Campus. The keywords that were used for the study included sustainability initiatives, sustainability, mission, vision, community, community engagement, and accreditation.

3.2 Reliability & Validity

The dependability of the data refers to the time and conditions of the study (Polit & Beck, 2014). Dependability is similar to reliability in quantitative investigation but differs in understanding stability of conditions that are dependent upon the nature of the study (Connelly, 2016). The study established dependability by selecting qualifying and applying research strategies, procedures, and methods that clarified its effectiveness and was evaluated by the researcher and confirmed by another researcher. In this study, we created an audit trail for the coding of data using both Microsoft Word® and Excel®.

Triangulation is the process of verifying evidence from different individuals, types of data, or methods of data collection. The data came from multiple areas, which included the official websites, sustainability reports, and accreditation documents. Through triangulation of the multiple data sources, it allowed the researcher to analyze the phenomenon from a different angle. Data source triangulation was used to support the credibility of findings. Phases involved in triangulating the data collected, and the subsequent findings were reviewed at multiple levels with different researchers (Connelly, 2016). An audit trail was established to document every aspect of this study.

The sample size should be chosen that will yield rich quality data and the best opportunity to achieve saturation. Data saturation was established once the data collection reached a point that no new data or themes were developed. Steps to triangulate the data collected was through the use of public documents and websites. This process would allow for the findings to be replicated using the same data that was used for the study.

As noted earlier, this exploratory study used a content analysis approach to

analyze existing information on the respective schools' website as that repository offered the most observable communication channel utilized for promoting sustainability initiatives, reporting and the evidence of actions to their stakeholders. Additionally, the qualitative content analysis directed or deductive method was employed by the research questions that, in turn, guided the creation of the categories needed for the sustainability initiatives and actions to their stakeholders (Mayring 2014). To maintain the integrity of the research throughout the study steps noted in the reliability, validity sections were implemented. Additionally, credibility was confirmed by triangulating findings obtained from the multiple sources of data.

Cooper and Schindler (2014) note that a qualitative study allows the researcher to achieve a deeper understanding of a phenomenon. Qualitative research is a measurable way of imaging the world. The primary goal of a qualitative study is to analyze for trends and relationships in the collected data (Watson, 2014). This qualitative exploratory approach was used to explore how greater stakeholder inclusion can lead to authentic engagement with sustainability initiatives and actions to produce change agents (in the short term) and change leaders (in the future workplace). The exploratory study design enabled the researchers to examine patterns and themes and ascertain new findings regarding stakeholder inclusion with sustainability initiates and actions that produce change agents and leaders.

4 Results

4.1 Sustainability in STEM HEI academic programs

The literature offered numerous strategies for implementing sustainability into HEI programs such as new courses on sustainability, sustainability lectures added to existing programs, embedded sustainability, or specializations/degrees in sustainability (Mulder et al., 2012; Staniskis and Katiliute, 2016; Thurer et al., 2018). Some research suggested a specific, integrated curriculum based on sustainability that targets engineers

(Lozano & Lozano, 2014). Other studies suggested 'hybrid learning' that emphasizes citizenship, broader societal and cultural concerns and working as a team to solve wicked and complex problems (El-Zein and Hedemann, 2016). In our study, STEM HEIs varied in the number of courses that are sustainability or sustainability-related. Some STEM HEIs offered numerous courses on sustainability or sustainability-related topics: Worcester Polytechnic Institute (149 courses), MIT (38 courses), Cornell (50 courses), University of Portland (38 courses). Other schools offered minors in sustainability (Rice University), forums or conferences on sustainability (U. S. Naval Academy), or mandatory volunteer service (the United States Coast Guard Academy). One innovative project derived from students in the Eco-Village at North Caroline State University who compiled a list of 359 courses which included sustainability or sustainability-related topics.

The accreditations for each of the top 20 STEM US HEIs are listed in Table 2. Many of the top 20 schools hold globally- recognized accreditations for general education from the New England Association of Schools & Colleges (NEASC) or Middle States Commission on Higher Education (MSCHE). However, all of these schools also hold an ABET accreditation, which is proof that a collegiate program has met standards essential to produce graduates ready to enter the critical fields of STEM education. This is important as the ABET accreditation standards include clear criteria for sustainability as applied to engineering. Thus, it could be expected that top-tier STEM HE institutions with engineering programs would be accredited with ABET.

Table 2

Accreditations for Top 20 STEM Schools

Institution	ABET	NEASC	AACSB	MSCHE	NAAB	WASC	OTHER
Massachusetts Institute of Technology	X	X					
United States Naval Academy	X			X			
Cornell University	X			X			
Rice University	X				X		Southern Association of Colleges and Schools Commission on Colleges

United States Air Force Academy	X		X				Higher Learning Commission
California Institute of Technology	X					X	
Harvey Mudd College	X						Accrediting Commission for Senior Colleges and Universities of the Western Association of Schools and Colleges
Carnegie Mellon University	X		X	X	X		Network of Schools of Public Policy, Affairs, and Administration
John Hopkins University	X						
Georgia Institute of Technology	X						Commission on Accreditation of Medical Physics Educational Programs
Cooper Union	X						
Case Western Reserve University	X						
United States Coast Guard Academy	X						
Rensselaer Polytechnic Institute	X						
Colorado School of Mines	X						Higher Learning Commission of the North Central Association
Worcester Polytechnic Institute	X	X	X				
California Polytechnic State University, San Luis Obispo	X				X	X	
University of Portland	X		X				Northwest Association of Schools and Colleges Commission on Collegiate Nursing Education
Rose-Hulman Institute of Technology	X						Higher Learning Commission
North Carolina State University, Raleigh	X				X		Southern Association of Colleges and Schools Commission on Colleges

Sources: All information on the tables was adapted from the information available on the official school websites in July 2018 and may have been modified since.

4.2 Communicating sustainability initiatives/actions to stakeholders

As seen in the literature, STEM HEIs institutions have begun to shift the focus in STEM education to finding long term sustainable solutions for short duration problems (Mulder et al., 2012), often linked to the issues emanating from the local community. Community engagement was emphasized on all of the top 20 STEM HEIs institutions' websites utilized in this study (See Figure 2). The most pervasive type of community engagement project was an Outreach program that encouraged young

people in the surrounding communities to pursue STEM careers. For the most part, these Outreach programs offered a variety of programs and services to engage and inspire students from K-12 to become the next generation of STEM students.

Another community engagement initiative was volunteer service, both in the local community and abroad. Some schools have an Office of Community Engagement (Harvey Mudd College and North Carolina State University) or promote their community partnerships (California Institute of Technology, Carnegie Mellon University, John Hopkins University, Georgia Institute of Technology, United States Coast Guard, and Worcester Polytechnic Institute). A unique requirement for all students at Worcester Polytechnic Institute is the completion of an Interactive Qualifying Project (IQP). The IQP expectations are for the student to develop a project that will formulate a solution that is based on the intersection of science and technology and society. Admirably, to date, 204 sustainability-related IQP projects have been completed by students at Worcester Polytechnic Institute. STEM HEIs institutions also offer community engagement closer to home, i.e., on campus. All of the schools in this study highlighted the sustainability initiatives were taking place on campus. These schools were noted to be engaging in the same sustainability initiatives that they are asking their students to participate in on or off-campus.

The 20 STEM HE institutions were involved in 102 total community engagement projects. All projects were coded into the applicable sustainability pillar: Environmental, Social, or Economic. However, there were some projects that 2 or 3 categories applied, so those initiatives were coded for all pillars. Figure 2 provides an interesting perspective and insight as we often hear so much about environmental initiatives, and, in actuality, the chart reflects a much higher percentage of the projects are based on social initiatives followed by economic initiatives.

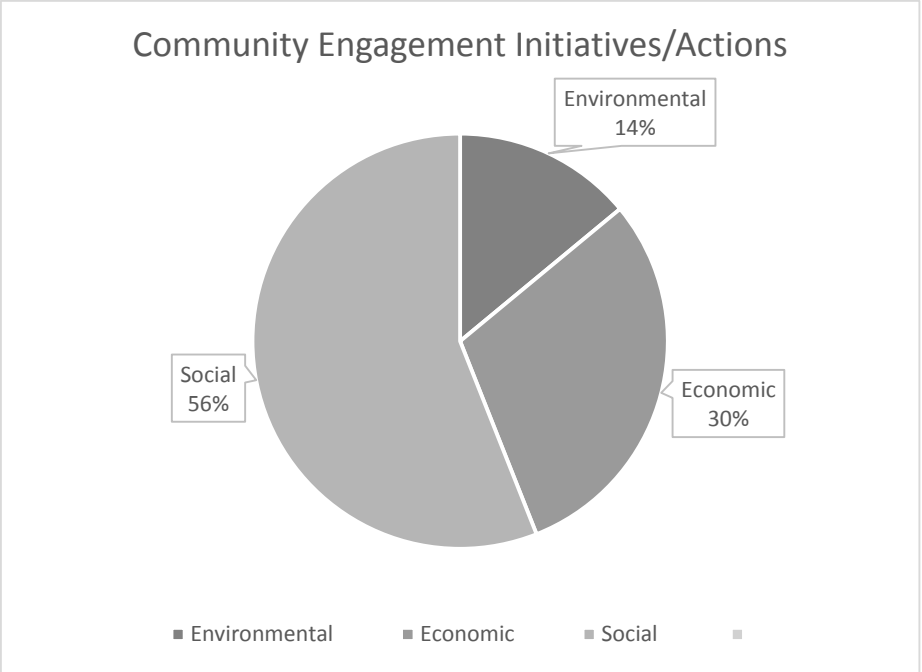

Fig. 2. Sustainability pillars related to community engagement.

In coding the stakeholders for the 102 community engagement projects, individual stakeholders were identified in the data collection. For the illumination of the key themes, a word frequency diagram was developed depicting the highest number to the lowest number of stakeholders in the projects. While the stakeholders changed throughout the community initiatives, the word frequency reflected that all projects were tied to three themes: Global Communities, Community Partners, and Community Business.

Community engagement entails efforts from the community, students, partners, staff, and faculty, on both a local and global scale. Each action has repercussions on the other stakeholders involved, which must be taken into consideration when considering or implementing new sustainability initiatives.

While economic and social initiatives were emphasized in sustainability initiatives off-campus, the story is quite different from sustainability initiatives on-campus. Table 3 demonstrates what these STEM HEIs highlight for sustainability on-campus and how many of the top 20 institutions offer the same or similar initiatives.

From the social initiatives, all 20 STEM HEIs offered volunteer sustainability projects both on and off campus and 18 hosted student sustainability committees. However, the most prevalent sustainability result noted was within the economic pillar, where all 20 STEM HEIs included scholarships, donations, and fund-raising as sustainability initiatives. While the environmental pillar is the most often cited by students when considering sustainability, the actions on the campuses varied: Approximately half of the top-ranked STEM HEIs in this study had initiatives for recycling, climate action plans, or campus energy.

Table 3

Sustainability Initiatives-On-Campus

Sustainability	On-Campus	Number
Environmental	Sustainability reporting	14
	Recycling	11
	Climate action plan: Greenhouse gas goal/emissions reduction	10
	Campus energy	9
	STARS rating	8
	Waste management/Zero Waste	8
	LEED-certified buildings	5
	Environmental awards	5
	Green transportation	5
	Conservation/Water	4
	Food	4
	Office of Campus Sustainability	2
	Green labs	1
	Environmental, health, and safety	1
Social	Volunteer sustainability projects (on and off campus)	20
	Student sustainability committees	18
	Sustainability hubs/centers	3
	Mandatory volunteer service	2
Economic	Scholarships	20
	Donations (alumni) to the institution	20
	Fund-raising	20
	Food Bank	1

When viewed in a figure format, the number and diversity of environmental actions are much more consequential than the social or economic actions communicated on the official websites. Nonetheless, three of the economic initiatives, scholarships, donations, and fund-raising appeared on all 20 STEM HEI websites. The only other criteria promoted by all 20 HEIs from the three sustainability pillars were volunteer sustainability projects (on or off campus).

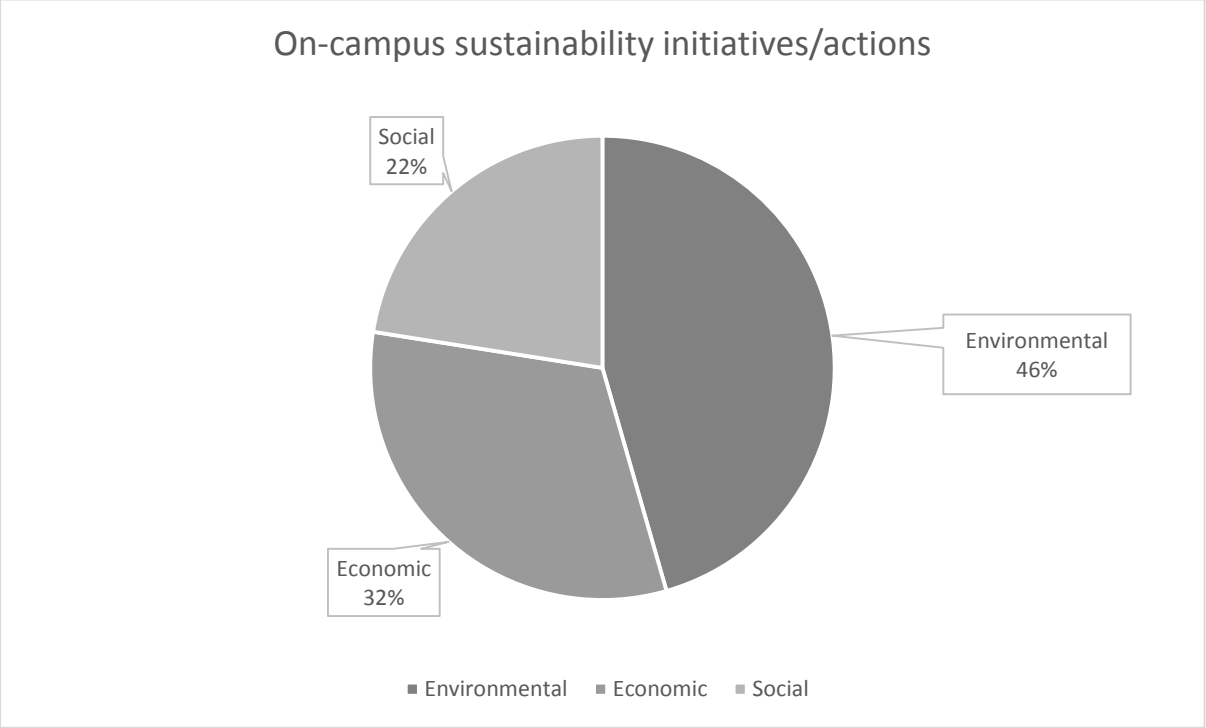

Fig. 3. Sustainability initiatives on-campus.

As seen in Table 3 and Figure 3, the sustainability on-campus initiatives that are the most prevalent are environmental initiatives. One or several environmental initiatives are highlighted and detailed on each of the STEM HEI's websites. The on-campus focus appears to favor environmental sustainability projects over social and economic ones. For the social and economic sustainability initiatives, volunteer projects, scholarships, donations, and fund-raising were accessible on all of the institutions' websites.

4.3 Mission and Vision

Engaged institutions include principles of sustainability in the mission and vision statements (Staniskis and Katiliute, 2016) and transform the curriculum to match the mission and vision (El-Zein and Hedemann, 2016). This is done to publicly communicate their commitment to sustainability across all levels of the HEI and the most extensive array of stakeholders (Lozano and Lozano, 2014; Staniskis and

Katiliute, 2016). In this study, too, sustainability was a prominent topic in the mission and vision statements of these top-tier STEM HEIs. Specifically, phrases such as 'betterment of humankind', 'enhance the lives and livelihoods', 'benefit society', 'understanding the impact of their work on society', 'impact on society', 'well-being of society', 'transforming society', 'envisioning the future', 'serving the American public', 'create global prosperity', 'global reach and global impact' emphasized the positive affect STEM graduates could have when dealing with the world's challenges. These phrases also suggest a particular emphasis on the greater community and the obligation for STEM graduates to address problems with sustainable solutions. Further, these phrases align with the philosophy and promise that ABET-accredited schools hold, i.e., a concern that their STEM graduates will be prepared to face critical challenges and make effective decisions for the greater society.

Other common themes that appeared in the mission and vision statements include leadership, diversity, and engagement. More than half of the STEM schools (12) included the word 'leader' or 'leadership' in the mission/vision statements, and three other school inferred leadership through phrases such as 'global citizens', 'member of the community', or 'people who respond to the needs of the world'. Seven of the schools emphasized 'diversity' in their mission and vision statements, while others referred to 'openness', 'creativity', or 'creative solutions'. Regarding engagement, only five of the STEM HEIs specifically employed the term 'engagement' or 'engaging' in their mission/vision statements.

5. Discussion

5.1 Sustainability framework

While HEIs have made noble concerted efforts to contribute to sustainable development through sustainability courses, programs, certificates, committees, mission statements, and other initiatives, the actual application and any standardization were

absent in the findings. As such, a gap remains in how sustainability initiatives and concepts are implemented in top tier U.S. STEM programs and, conversely, how effective the measures are in increasing authentic student engagement during and after their studies. Subsequently, the uneven application could increase or decrease the overall reputation of the HEI. This proposed framework is based on the results of the best practices identified in the research as well as the pragmatic perspective that is needed by STEM students to make the leap from theoretical example to concept or application (Gasiewski, Eagan, Garcia, Hurtado and Chang, 2012, Ibrahim, Aulls and Shore, 2017, Ferrara, Talbot, Mason, Wee, and Rorrer, 2018). By beginning at an institutional level through mission and vision statements that directly address sustainability, educators can embed sustainability into their programs and courses. This should lead to sustainability-based initiatives led by the faculty or the students both on and off campus. Additionally, community projects and service imparts the importance of sustainability needed today and in the future (Varela-Candamio, Novo-Corti, and Garcia-Alvarez, 2018; Walker, 2015). By partaking in sustainability-based initiatives, students will apply the often abstract concepts of sustainability into real-life experiences that will follow them into their professional careers. In this manner, they become the change agents for the future. This process is illustrated in the preliminary framework depicted in Figure 4. Further research will formalize the sustainability framework design that will be applicable to STEM HEIs that emphasize social sustainability, community engagement, and, subsequently, higher reputation ratings.

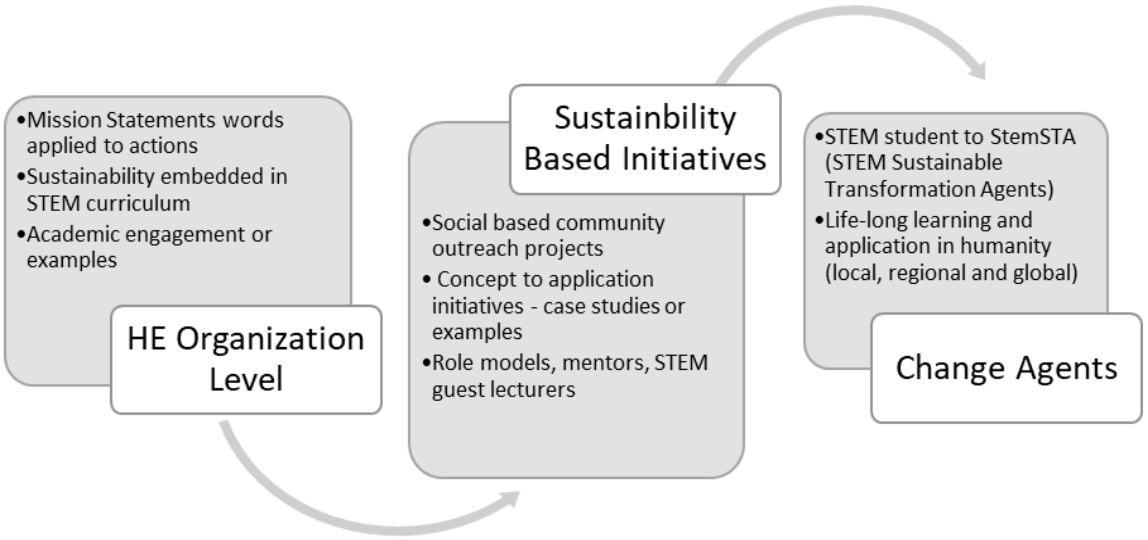

Fig. 4. Sustainability Framework

The findings in this exploratory phase of research have significant policy and strategic implications for the future STEM HEIs that embrace sustainability principles and have the ambitious goal of creating the next generation of change agents (Verhulst and Lambrechts 2015).

As illustrated in the Results section, it was clear that the number and variety of environmental actions are more prevalent than the social or economic actions communicated on the official websites of the universities. However, three of the economic initiatives, scholarships, donations, and fund-raising appeared on all 20 STEM HEI websites. The only other criteria promoted by all 20 STEM HEIs from the three sustainability pillars perspective was on and off-campus volunteer sustainability projects. From this information, researchers can infer that the approach or focus on sustainability is fractured and lacks a synthesis in tying the initiatives together by the 20 STEM HE institutions. Admittedly, many of the aforementioned economic areas are philanthropy driven and found at virtually every university. Likewise, the majority of

universities encourage students to participate in volunteer opportunities that broaden social and life skills to prepare students for the work environment after college. However, for the 20 STEM HEIs examined in this research, the opportunity to link the initiatives together was missed that would offer the holistic or systems-based perspective that is critical to grasping and, in turn, implementing sustainable actions. This study considers the three pillars of sustainability, but in actuality, the three areas should not be considered as pillars as that visual connotes stand-alone or separate aspects. Sustainability is a system of systems with each facet environmental, economic and social relying on and feeding into the other areas. A better approach is to use a Venn diagram similar to the one in Figure 5 when designing, developing, and implementing sustainability into curricula and campus activities. By employing this type of approach, the interconnections between the different types of initiatives are better visualized. The interconnection of the three pillars were arrived from key words that were developed from the on-campus and mission/vision sustainably initiatives. For example, the on and off campus volunteer initiatives certainly met the social sphere depicted in Figure 5, but as the volunteer projects were offered as service commitments the economic benefit is obvious too. Additionally, on and off campus volunteer projects were primarily carried out in the local area and environmental component is also recognizable. With all three spheres included in the on and off campus volunteer initiative it can be viewed as an endeavor that meets all the tenets of a sustainable effort.

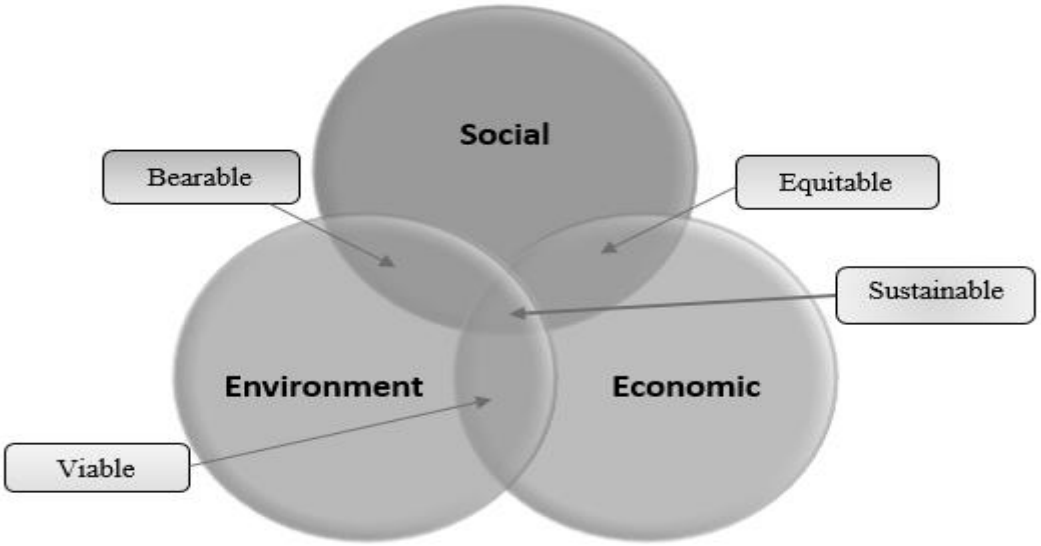

Fig. 5. Simple Venn Diagram for Sustainability.

To summarize, the 20 top-tier STEM HEIs were not only offering a stand-alone course or two; instead, they are partaking in specific actions and initiatives for the communities in which they reside. They have embedded sustainability into the campus community lives for the students and outreach to the local communities. Therefore, the following specific answers to the research questions are offered.

5.2 Sustainability in STEM HEI academic programs

The literature (Hopkinson and James, 2010) reflects a gap between sustainability concepts taught in the classroom and the daily life of the student. However, consistently across the 20 STEM HEIs, all had many sustainability-related initiatives that reinforced the concepts from the classroom. Not all of the 20 STEM HEIs had programs in sustainability. However, most had several classes in the programs that provided the student with an understanding of sustainability-related issues which aligns with the previous research on embedding sustainability into existing programs (Jones Christensen, Peirce, Harman, Hoffman, and Carrier, 2007; Seto-Pamies and Papaoikonomou, 2016; Sidiropoulos, 2014; Verhulst and Lambrechts, 2015; Zizka and McGunagle, 2017). Nonetheless, the number of sustainability courses, programs, and initiatives is often

linked to the size of the HEI which needs to be considered as well (Zizka et al., 2018).

There seems to be no right or effective way to integrate sustainability into STEM academic programs. As seen in the literature, merely proposing sustainability courses (stand-alone) or giving lip service to embedded sustainability within programs offers little opportunity for students to engage with sustainability. In fact, 'greening' the curriculum or focusing on 'light green' actions may have the opposite effect and produce students who are cynical about their impact (short term) and disengaged with sustainability practices (long term). According to Swaim et al. (2014), student attitude has the strongest influence on sustainability intention. Thus, the need for new courses which are interdisciplinary and multidisciplinary and include action-based, real-world, and work-based contextual environments proposed in the previous literature (Clark and Button, 2011; Kennedy and Odell, 2014; Kurland et al., 2010; Mochizuki and Fadeeva, 2010; Muller-Christ et al., 2014; Zizka and McGunagle, 2018) has been confirmed in this study as well. As it is the responsibility of HEIs to provide knowledgeable and educated change agents who will replicate sustainability initiatives in their professional careers (Clark and Button, 2011), this study confirms the need for further progress in this domain.

Even with the progress made towards incorporating sustainability into academics and actions at top STEM HEIs, there is still work to be done. The challenge now is to move sustainability from separate concepts to a more practical and even logical way of everyday thinking that, in turn, will generate genuine change agents. In the future, more emphasis must be placed on the intersections between the sustainability pillars that create a system. For example, the volunteer sustainability projects (on and off-campus) from Table 3 and Figure 3 and discussed in relation to Figure 5 can be utilized. The volunteer sustainability projects (on and off-campus) were identified as a social initiative. However, in Figure 6, some example areas of interdependence or

influence are offered to illustrate why a sustainability-based project should not be designed, identified, or implemented as benefiting only one pillar or circle.

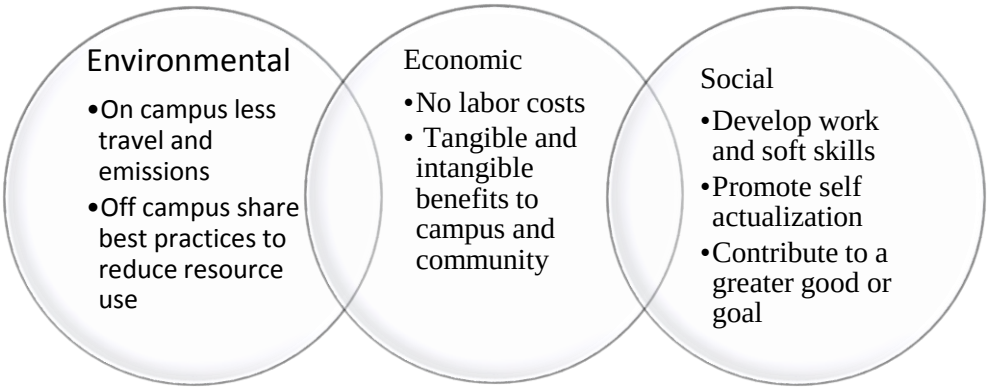

Fig. 6. Volunteer Sustainability Projects (on and off campus) graphic

By instilling the basics of systems thinking early in academic programs and designing initiatives with all three pillars of sustainability in mind, students will become more agile thinkers when faced with complex issues in the future.

5.3 Communicating sustainability initiatives/actions to stakeholders

As seen in our content analysis of the official school websites, STEM HEIs include sustainability in their communication efforts. 75% of the 20 STEM HEIs had sustainability reports, and 50% have listed their awards on their website. All of the institutions had reported their sustainability initiatives in great detail. The 102 sustainability initiatives offered a view of the importance of sustainability as a HEI and to their student body. 20% of the STEM HEIs had a website page that was dedicated to sustainability. For any stakeholder who peruses these STEM HEI websites, they will find ample examples of sustainability initiatives and actions. However, simply communicating these actions on the HEI website does not guarantee replication of sustainability initiatives or actions by the faculty or students. Further, there is scant information on the number of stakeholders who participate in these actions. As seen in

the literature, this communication on the websites could be considered part of the 'rhetoric-behavior' gap where sustainability is discussed but the behavior does not follow. HEIs need to facilitate and communicate the action phase of sustainability as well.

The initial purpose of this paper was to focus on the social sustainability initiatives communicated by the top-ranked STEM institutions and the potential of these initiatives to produce greater stakeholder engagement, especially students, in all three pillars of traditional sustainability. Nonetheless, as seen in this study, economic and social sustainability initiatives are communicated more frequently than environmental initiatives when the project is off-campus. In contrast, the communication of environmental sustainability initiatives continues to dominate for on-campus activities. This difference could explain why previous literature concluded that environmental initiatives are the most often cited by students. If their on-campus life is inundated with sustainable environmental practices, they would be more aware of these actions and, subsequently, make sustainable choices as students and, potentially, replicate these actions upon graduation.

5.4 Mission and Vision

As a topic of extreme relevance to STEM programs, sustainability, particularly the link to dealing with global challenges and solving global issues, was well-documented in the mission and vision statements of all STEM schools in this study. Mission and vision statements are written at a strategic level of the HEI to reflect the overarching philosophy of the institution. These statements synthesize the essence of what the school believes in and offer concrete directions that all member of the HEI can follow. As seen in the literature, HEIs seek recognition through external accreditation bodies such as AACSB and NEASC which recognize what is taught within a HEI and how it is implemented. These accreditation bodies focus on quality improvement that

encourages engagement, innovation, and impact. When written well, the mission and vision statements reflect the characteristics that the highest accreditations seek. While these top-tier schools refer to the betterment of the community and its citizens, only 25% specifically employed the term 'engagement' or 'engaging' in the respective mission/vision statements. Thus, while community engagement is only inferred in the mission/vision statements of the majority of these schools, it is embedded in the very fiber of the universities and carried out in a myriad of ways beyond the guise of sustainability.

6. Conclusions

In this research, the authors sought to illustrate a link between the top 20 U.S. STEM HEIs and the sustainability initiatives the leaders undertake for the betterment of the greater society, with a particular focus on community engagement practices. While not stated overtly to this point, the theoretical contribution of this research is founded in the transformative learning theory developed primarily by Jack Mezirow (1991) that is a process for effecting change in a frame of reference or perspective. While the theory is focused primarily on adult learners, the STEM student is an ideal candidate for applying the transformative learning theory to sustainable development as well. STEM students are by nature inquisitive but pragmatic in their learning processes. Theory or instrumental learning is important but application and communicative learning connect theory to real world experiences. STEM educators can play a key role in making the students aware and most importantly critical of theirs and others' preconceived assumptions, i.e. sustainability is just about the environment. Sustainability is a holistic way of thinking and the transformative learning theory focuses on "…. discovering the context of ideas and the *belief systems* that shape the way we think about their sources, nature, and consequences, and on imagining alternative perspectives" (Mezirow, 1997, pg. 11). Consequently, by challenging those preconceived ideas and beliefs through

theory and project applications STEM educators can create "socially responsible autonomous thinkers" (Mezirow, 1997, pg. 8). These autonomous thinkers are critically reflective and their beliefs are honed through discourse and validation and will become more valuable practitioners in their respective fields. Autonomous thinkers are the envisioned change agents needed to ensure that sustainable development continues to evolve in the workplace.

What the authors discovered confirms the initial premise that the leaders in STEM education who will be expected to produce graduates that develop innovative and creative solutions to the world's most complex problems are making great strides to include sustainability concepts within their curriculum, both on and off-campus. The U.S. top-tier STEM HEIs are not simply offering a stand-alone course or two; rather, they are partaking in specific actions and initiatives for the communities in which they reside. They have embedded sustainability into the campus and community for both the students and the community.

Despite the sustainability initiatives and projects examined in this study, there is room for improvement. This study began by asking the question: How can greater stakeholder inclusion lead to authentic engagement in sustainability initiatives and actions to produce change agents and change leaders? The following is a response that derived from this study. Firstly, prestigious accreditations need to provide concrete and consistent criteria in regards to teaching and embedding sustainability in HEIs. Secondly, mission and vision statements could be better aligned with the expectations of the greater community in which the HEI is situated. Thirdly, while HEIs are participating in community engagement projects, an audit could be conducted to confirm the effectiveness and usefulness of these projects to the greater community and the students themselves. Finally, research needs to be done on a national and international scale to establish the most effective way to embed sustainability into HEI courses and programs,

regardless of discipline or school, to encourage authentic student engagement that will continue into their future workplace.

Lastly, this study has several limitations. While several universities also complete sustainability initiatives, it was the researchers' premise that the top 20 STEM HEIs would be leaders in sustainability initiatives. The initial study was limited to the top 20 STEM HEIs in the U.S., so additional studies should be completed to cover a higher number of STEM schools, both nationally and internationally. Supplementary data collection could be done through sustainability posts via social media platforms to analyze stakeholder engagement and examine the effectiveness of the actions on reputation. The 20 STEM HEIs in this study employed a variety of ways to ensure that the students embraced sustainability initiatives both inside and outside the university. Still, the effectiveness of these initiatives is yet to be studied in order to formalize the sustainability framework better. The literature highlighted the value-behavior gap. While students may participate in these projects on campus or during their studies, this research does not offer any evidence that these students or any other students will replicate the sustainable initiatives in the real world.

One further limitation that should be highlighted is the access to course information. While many more sustainability or sustainability-related courses could be offered, it would entail a much more detailed analysis and examination of course learning outcomes or content to accurately reflect the reality of teaching sustainability in the respective programs. Further studies should reflect on student experience gained in the sustainability initiatives, the impact on the students' learning, and, in turn, their professional and personal lives.

The lack of sustainability knowledge to action evidence found in this research is the critical area that requires further study. The question lies in how sustainability is presented from three different pillars rather than as an interconnected system; thus, an

actual gap may exist in the comprehension of faculty members who design and teach the courses or programs. That inferred lack of understanding follows on to the projects and other initiatives offered by the 20 STEM HEIs studied. Additional research is essential to better understanding if this perceived gap in systems knowledge is real or if the issue is the conveyance of the information to the students in a comprehensive manner. This apparent gap should be investigated first in order to comprehend where the tangible gaps in knowledge reside. If the issue is a lack of systems based knowledge, then more correlation to systems engineering tenets is required and aspects of existing engineering courses could be added to sustainability focused courses. However, if the shortfall is found to be in articulating systems thinking to sustainability then the primary problem may be resources to support or augment systems based thinking. In this case, the institutions should invest in adding new or non-traditional sources to the curricula and sustainability initiatives, particularly business or organizational type resources that round out the social and environmental aspects of the present courses and or initiatives. The envisioned follow on research to this the exploratory study, should include interviews of students, faculty, and school administrators that could enhance the development in this area. The research goal of this study was to develop the preliminary framework depicted earlier in Figure 4. Further research as described above will formalize the sustainability framework design and apply it to STEM HEIs that emphasize social sustainability, community engagement, and, subsequently, higher reputation ratings.

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*Declaration of Interest Statement

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Sustainability in Science, Technology, Engineering and Mathematics (STEM) programs: Authentic engagement through a community-based approach

Higher education Science, Technology, Engineering, and Mathematics (STEM) programs currently offer the theoretical knowledge and industry-related competences that seek to prepare STEM graduates to be leaders to meet 21st century demands. In this research, the authors examined the top 20 STEM Higher Education Institutions (HEIs) in the United States with a goal of establishing any obvious nexus between school reputation, sustainability approaches, and community inclusion. The underlying premise rested in the assumption that schools with the highest STEM program reputation are also the leaders in sustainability initiatives and projects in the respective academic and geographical communities. The findings revealed that on-campus efforts mainly focused on environmental actions, while community engagement projects emphasized the social or economic principles of sustainability. Consequently, the lack of synthesis of projects or initiatives that linked all three tenets of sustainability was the identified gap between what students are learning theoretically in the classroom and the subsequent application in the real world. By making these critical connections, STEM HEIs will produce change agents with a more intrinsic perspective on sustainability rather than one that is gained in a piecemeal manner after they enter their respective professions. By utilizing the tenets of the transformative learning theory, the results from this exploratory study will be employed to create a future model for not only teaching sustainability in STEM programs but, by coupling theory with actions, the results will foster engagement that ensures sustainable development is not an objective but an ingrained mindset that is practiced in daily actions.

Keywords: Science, Technology, Engineering, and Mathematics (STEM) higher education institutions, sustainability actions/initiatives, local community, engagement, sustainability education

Highlights:

- Corroborated preceding research that STEM students learning best by experience or action
- Applied transformative learning theory to traditional STEM learning techniques
- The 20 US STEM schools largely included off campus community engagement projects to imprint sustainable concepts

- Social and economic based programs were the focus of the majority of sustainability based community projects
- Absence of perceived best practices or types of projects that connected sustainability to respective programs in the 20 US STEM schools

Sustainability in Science, Technology, Engineering and Mathematics (STEM) programs: Authentic engagement through a community-based approach

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Reviewers' comments:

Thank you for your comments. We have made all of the changes requested in this new version.

Reviewer #2: Dear authors,
The following changes are suggested:

1- Figure 3. One of the color boxes misses text, erase. Correct the "Environmental 46%" text.

This figure has been fixed to show all the data.

2- Figure 4. Check the text separation in the different boxes, each sentence it seems to overlap with the next one. Take out the red underlying below the words.

This figure has been redone to avoid the overlapping.

3- Abstract: "The results from this exploratory study will be utilized to create a future model for teaching sustainability that will foster engagement that can be replicated in other STEM programs to instill lifelong behaviors". Is this a course you will develop or practitioners' implications of the results? My suggestion is you rephrase this sentence in more general terms, with implications for practice. What is the contribution of the article to theory? In particular to education for sustainable development?

The last few sentences of the abstract were changed to the following:
By making these critical connections, STEM HEIs will produce change agents with a more intrinsic perspective on sustainability rather than one that is gained in a piecemeal manner after they enter their respective professions. By utilizing the tenets of the transformative learning theory, the results from this exploratory study will be employed to create a future model for not only teaching sustainability in STEM programs but, by coupling theory with actions, the results will foster engagement that ensures sustainable development is not an objective but an ingrained mindset that is practiced in daily actions.

4- Conclusion: the theoretical contributions are missing as well as the practitioners' implications of the research

The authors added in the theoretical contributions and implications under the Conclusion by including the following:

In this research, the authors sought to illustrate a link between the top 20 U.S. STEM HEIs and the sustainability initiatives the leaders undertake for the betterment of the greater society, with a particular focus on community engagement practices. While not stated overtly to this point, the theoretical contribution of this research is founded in the transformative learning theory developed primarily by Jack Mezirow (1991) that is a process for effecting change in a frame of reference or perspective. While the theory is focused primarily on adult learners, the STEM student is an ideal candidate for applying the transformative learning theory to sustainable development as well. STEM students are by nature inquisitive but pragmatic in their learning processes. Theory or instrumental learning is important but application and communicative learning connect theory to real world experiences. STEM educators can play a key role in making the students aware and most importantly critical of theirs and others' preconceived assumptions, i.e. sustainability is just about the environment. Sustainability is a holistic way of thinking and the transformative learning theory focuses on "…. discovering the context of ideas and the belief systems that shape the way we think about their sources, nature, and consequences, and on imagining alternative perspectives" (Mezirow, 1997, pg. 11). Consequently, by challenging those preconceived ideas and beliefs through theory and project applications STEM educators can create "socially responsible autonomous thinkers" (Mezirow, 1997, pg. 8). These autonomous thinkers are critically reflective and their beliefs are

honed through discourse and validation and will become more valuable practitioners in their respective fields. Autonomous thinkers are the envisioned change agents needed to ensure that sustainable development continues to evolve in the workplace.

Reviewer #3: Comments on JCLEPRO-D-20-01144R2
Dear Authors, the review report on the above numbered manuscript is given below.
Summary and overall evaluation:
The manuscript entitled as "Sustainability in Science, Technology, Engineering and Mathematics (STEM) programs: Authentic engagement through a community-based approach," is in much better and refined form than before. The authors have put in great effort to bring about quality in it. Thus, the manuscript, in the present form, fulfils the criteria of publication in the Journal of Cleaner Production. A last point is just to go through with reference to language. There are some sentences that need to be in the past form but they are in future form. This will give the fine tune to the manuscript.

Thank you for your comments. A final edit was done to check specifically for language inconsistencies.

Highlights:

- Corroborated preceding research that STEM students learning best by experience or action
- Applied transformative learning theory to traditional STEM learning techniques
- The 20 US STEM schools largely included off campus community engagement projects to imprint sustainable concepts
- Social and economic based programs were the focus of the majority of sustainability based community projects
- Absence of perceived best practices or types of projects that connected sustainability to respective programs in the 20 US STEM schools