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Assessing curricula contribution to sustainability more holistically: Experiences from the integration of curricula assessment and students' perceptions at the Georgia Institute of Technology

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ABSTRACT

There has been a rapid increase on the number of engineering schools in higher educational institutions that have incorporated sustainability into their teaching. Nonetheless, curricula reforms are still needed to better educate engineers on the implications that their work has on the environment and societies in this generation and future ones. A step to facilitate this is assessing the contribution of engineering curricula to sustainability. This assessment can provide a starting point on how sustainability is being taught, and how this can be improved. This paper presents the results from the assessment of the sustainability content of the Civil and Environmental Engineering curriculum at the Georgia Institute of Technology using two complementary approaches: the Sustainability Tool for Assessing UNiversity's Curricula Holistically system and two students' perceptions surveys. The results from the curriculum assessment indicated that the courses addressed mainly environmental issues, and that the depth of coverage could be improved. The results from the students' surveys concurred with the curriculum assessment, although there were some differences in regard to social issues. Using both approaches provides a more holistic overview of the contribution of engineering courses and degrees to sustainability, and it allows detecting discrepancies between sustainability content in the syllabus and sustainability teaching in the classroom. The approaches can help to foster educational changes by: guiding university leaders in devising curricula reforms to promote sustainability learning; providing students with opportunities to reflect upon the topic; and bridging the gap between the activities being done at the university to foster sustainability and student perception of what needs to be achieved.

1. Introduction

Sustainable development (SD) has emerged as an alternative for addressing and overcoming activities such as over-population, resource over-consumption, and environmental degradation that have resulted in damage to the Earth's environment and quality of life for this generation and future ones (Carley and Christie, 2000; Dalal-Clayton and Bass, 2002; Korten, 2001; WCED, 1987). Lozano (2008) proposed that a holistic perspective, which balances the four dimensions (economic, environmental, social, and time) is required to promote SD. Nonetheless, it is recognized that, usually, sustainability tends to refer solely to environmental sustainability (Atkinson, 2000; Costanza et al., 1991; Rees et al., 1998; Reinhardt, 2000), while the social dimension is in many cases neglected (Salzmann et al., 2005).

An increasing number of universities have been engaged in incorporating and institutionalizing SD into their curricula, research, operations, outreach, and assessment and reporting, as well as engaging with internal and external stakeholders (Cortese, 2003; Lozano, 2006; Velazquez et al., 2005). Within these activities, there has been growing interest in embedding SD into the curricula at all levels, particularly in terms of students gaining an understanding of how their decisions and actions affect the environment and society (Lozano, 2010a; Lozano and Peattie, 2009).

In this context, engineering schools have been pioneers in incorporating SD and sustainability science into their curricula

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(Fenner et al., 2005; Glavic et al., 2009; Segalàs, Mulder, & Ferrer-Balas, 2012). Such schools have been educating students about the complex nature of global and local dilemmas, as well as how to understand and balance their interrelated technical, economic, environmental, and social dimensions (Davidson et al., 2007). Although many institutions have recognized the need to educate sustainability-conscious engineers, the emphasis on adding new sustainability courses into an existing curriculum may be interpreted as sustainability being apart from or as an afterthought within the curriculum design process (Peet et al., 2004), rather than as an integral part of sustainable engineering. In spite of this, there have been calls (e.g. the National Academies Press (NRC, 2004)) for significant changes to integrate sustainability content into undergraduate engineering curricula to properly equip students to tackle complex global dilemmas.

This research is aimed at answering the following research questions: (1) What is the extent of integration of sustainability across engineering curricula? (2) What are student perceptions of the contribution of courses to sustainability? and (3) What can be learned from integrating curricula assessment and student perceptions of sustainability integration? To answer these questions this paper presents the results from a systematic curricula assessment and students' perceptions of the undergraduate civil and environmental engineering (CEE) curriculum at the Georgia Institute of Technology (Georgia Tech) in the United States of America (USA).

The remaining parts of the paper are structured in the following way: Section 2 comprises a discussion on sustainability integration into higher education institutions' curricula and stakeholders' perceptions; Section 3 discusses the methods used, including the case study, the details on the curricula assessment system, and the student perceptions survey; Section 4 offers the results from both methods, and compares and contrasts these; Section 5 provides an overall discussion; and Section 6 presents the conclusions.

2. An overview of sustainability integration into higher education institutions' curricula and stakeholders' perceptions

This section presents an overview of two research fields that have been generally separated in the literature: sustainability integration into higher education institutions' curricula, and stakeholders' perceptions of education for sustainable development (ESD).

2.1. Sustainability integration into higher education institutions' curricula

In general, most higher education institutions' (HEIs) curricula have been based on disciplinary specialization and reductionist thinking (Cortese, 2003; Lovelock, 2007; Lozano, 2010), which has resulted in education that is unbalanced, over-specialized, and mono-disciplinary, and graduates who use their skill sets to solve problems by analyzing system components in isolation (Lozano, 2010). Nonetheless, a number of approaches for overcoming this and incorporating SD into curricula has been proposed, ranging from addressing a particular sustainability dimensions to offering a specialized SD degree (Lozano, 2010) (see Table 1).

Ceulemans and De Prins (2010) acknowledged two methods for effective incorporation of sustainability concepts into university curricula, horizontal and vertical integration. Horizontal integration is when sustainability concepts are incorporated into several courses across a curriculum, while vertical integration involves the addition of new sustainability courses into an existing curriculum. The latter has been recognized to be essential for teaching students about fundamental concepts and principles related to sustainability; however, adding a new course with sustainability content into a curriculum may be insufficient since teaching students about sustainability in isolation from core engineering concepts does not encourage them to incorporate sustainability into their professional designs and practices (Peet et al., 2004). The integration of sustainability into existing courses may aid students in viewing sustainability in a systemic and holistic manner by demonstrating how sustainability and technical content can be blended to create sustainable designs (Ceulemans and De Prins, 2010; Peet et al., 2004).

Table 1
Four approaches for incorporating sustainable development into higher education curricula. Integrating Ceulemans and De Prins (2010) and Lozano's (2010) research.

Integration strategy	Approach
Horizontal	• Some coverage of particular environmental and/or social issues and material in an existing course (Thomas, 2004). • SD intertwined as a concept within pre-existing disciplinary-oriented courses, with the relevant SD component issues matched to the nature of each specific course (Abdul-Wahab et al., 2003; Boks and Diehl, 2006; Peet et al., 2004). • SD offered as a specialization or major within the framework of particular faculties or schools (Kamp, 2006).
Vertical	• A specific SD course added to the curriculum (Abdul-Wahab et al., 2003; Thomas, 2004; von Blottnitz, 2006).

In spite of the recognized need to incorporate SD into curricula (Barth and Rieckmann, 2012; Shriberg, 2002), change has been little and slow (Boks and Diehl, 2006; Capdevila et al., 2002; Thomas, 2004; Velazquez et al., 2005) and there is still limited research on explaining the incorporation of SD into university curricula (Capdevila et al., 2002; Thomas, 2004; Velazquez et al., 2005).

Within the incorporation process of SD into curricula, three levels have been identified: (1) Major progress in embedding SD into undergraduate and post-graduate degrees; (2) Some limited progress; and (3) Relative difficulties in making credible and rigorous connections in courses and degrees, in spite of an interest in adopting the SD agenda (Thomas, 2004).

It has been proposed that curricula assessment can offer university leaders a starting point and catalyze embedding sustainability into courses (Barth and Rieckmann, 2012; Lozano and Peattie, 2009). Such assessments can highlight the courses and degrees that contribute to sustainability, as well as those where sustainability could be better incorporated (Lozano, 2010; Lozano and Peattie, 2011). This information can also be useful for initiating staff development projects (Barth and Rieckmann, 2012; Shriberg, 2002).

2.2. Students' perceptions of education for sustainable development

In recent years, a number of researchers have focused on investigating students' perceptions of sustainability (see Lozano et al., 2013; Wright, 2010; Wright and Wilton, 2012). These can be grouped into: (1) students' knowledge; (2) students' attitudes; and (3) attitudes and curricula.

A number of studies have addressed students' knowledge and awareness of sustainability from across the globe. The survey results of Barth and Timm (2011) indicated that students from Leuphana University in Germany ($n \geq 1000$) demonstrated a 'sophisticated' understanding of sustainability, although many students highly emphasized the environmental dimension.

Kagawa (2007) surveyed 1889 students at the University of Plymouth in the United Kingdom (UK), of which only one-third were either ‘very familiar’, ‘quite familiar’, or ‘quite unfamiliar/not at all familiar’ with the term SD. As with the Leuphana study, the results from the Plymouth highlighted the focus on the environmental dimension. Yuan and Zuo (2013) surveyed 1134 students from Shandong University in China where a majority of students indicated that they “[knew] to some extent” about SD. Tuncer (2008) reported that over 90% of surveyed students ($n = 828$) from Middle East Technical University in Turkey agreed with a basic definition of SD, with over half supporting environmental protection over economic growth. Bielefeldt (2011) adapted the Kagawa (2007) survey to study the sustainability knowledge of students at the University of Colorado ($n = 344$) in the USA, where more than half of the first-year students were only “slightly” familiar with the term SD, while almost half of seniors were “somewhat familiar”. Earl et al. (2003) found that over half of surveyed participants ($n = 100$) from students at the College of Charleston in the USA indicated that they “had not heard of the term [SD].” This was corroborated by Emanuel & Adams’ (2011) survey ($n = 406$) of university students from Alabama and Hawaii in the USA show that approximately one-third of students had little knowledge of sustainability. As it can be observed, the studies show that there has been a large range of SD perceptions and knowledge.

Other researchers have focused on students’ attitudes toward and actions related to sustainability. For example, Kagawa’s (2007) research revealed that Canadian students exhibited positive attitudes toward sustainability, with over 70% indicating that sustainability “[was] a good thing.” Barth and Timm (2011) indicated that some German students expressed that sustainability played a “strong” or “very strong” role in their professional (28.5%) and private (35.7%) lives. Lukman et al. (2013) used a survey to study the environmental attitudes of 107 primary school students in Slovenia, and found that environmental education addressed only approximately one-third of factors shown to impact environmentally-conscious actions. Rodriguez-Barreiro et al., 2013 examined the environmental attitudes of 60 graduates from the University of Zaragoza in Spain, who indicated positive student attitudes toward environmental conservation, as well as an intention to act, were likely to lead to pro-environmental actions. Zsóka et al. (2013) administered a survey to 770 high school and university students in Hungary found that environmental knowledge, commitment, and environmental awareness are strongly correlated with intensity of environmental actions. These studies show the increased interest from students and researchers on sustainability oriented attitudes.

In regard to attitudes and curricula, Tuncer (2008) indicated that enrollment in an environmentally-focused course to have no impact on sustainability knowledge. However, more recent research has contradicted this. For example, a study at the University of British Columbia (UBC, 2009) in Canada highlighted that students have overwhelming support for integrating sustainability into curricula, with a majority stating that sustainability should be taught in their programs, regardless of degree level or academic unit. Barth and Timm (2011) found sustainability-related coursework to impact sustainability awareness, since students pursuing a sustainability-related minor or major emphasized the social aspects of sustainability more than their peers only seeking disciplinary specialization. Bielefeldt (2011) determined that last year civil and environmental engineering students were more familiar with SD than their first-year counterparts. These studies show how embedding sustainability into curricula can have a positive impact on students’ attitudes towards sustainability.

Although there have been a number of studies on stakeholders’ knowledge and attitudes for sustainability, it is still a new and growing field, as indicated by Wright (2010) and Lozano et al. (2013). Nonetheless, studying stakeholders’ ESD perceptions and attitudes is critical for fostering sustainable practices on campuses (Earl et al., 2003), and has the potential to reduce the gap between what is being done and what is perceived to be done.

3. Research methods

This section presents the case study of the school of CEE at Georgia Tech, and the research methods (curricula assessment and students’ perception survey) used.

3.1. *Case study: the school of civil and environmental engineering at Georgia Tech*

Georgia Tech, founded in 1885, is located in Atlanta, Georgia, USA. The university is comprised of more than 900 full-time faculty and more than 21, 500 undergraduate and graduate students. Georgia Tech has a strong focus on technological research, with $655 million in research expenditures in 2011. As a result, the institution is consistently named one of the top ten public universities in the USA (Georgia Tech, 2013; US News, 2013b).

The School of CEE offers undergraduate bachelor’s degrees in civil and environmental engineering. The School is comprised of 54 full-time faculty members and almost 800 undergraduates. During 2011–2012, more than 200 undergraduates obtained degrees in CEE from Georgia Tech (Georgia Tech, 2012). When comparing similar programs from across the country, US News & World Report ranks both CEE programs among the top three (US News, 2013a). The undergraduate curriculum requires students to complete foundational math, chemistry, and physics requirements, in addition to numerous required engineering courses. Students are encouraged to explore their interests and/or further establish specializations by choosing from the over 40 CEE courses to meet flexible technical requirements.[1]

In relation to ESD, the School of CEE at Georgia Tech has incorporated two sustainability-focused courses into the curriculum (using mainly vertical integration). A civil engineering systems course (CEE 3000) was created in 1999 in response to a university-wide sustainability initiative (see Amekudzi and Meyer, 2004; Meyer and Jacobs, 2000). CEE 3000, compulsory for all CEE students, is intended to introduce students to sustainability from a systems perspective. The course includes three modules: Systems and Sustainability Perspectives; Systems Performance Analysis; and Economic Decision-Making Tools and Project Evaluation. In addition, students are required to complete a final project that requires a sustainability analysis of an existing civil infrastructure system. More recently, a new elective course entitled Sustainable Engineering (CEE 4803) was created for interested students to further enrich their knowledge of sustainability. This course included topics such as industrial ecology, Earth systems engineering and management, life cycle assessment, and material flow analysis. Students also collaboratively work to develop and apply class principles to a problem of interest. Thus, the CEE curriculum exposes all students to sustainability, while providing opportunities for motivated students to engage in more in-depth learning. It should be noted that incorporating some material or creating a SD course tends to result in the students learning and studying for that particular course, but not being able to integrate SD principles

[1] Additional details about the CEE curriculum can be found at http://www.ce.gatech.edu/academics/undergraduate.

Table 2
STAUNCH® 2010 curricula contribution to sustainable development assessment criteria.

Economic	Environmental	Social
• GNP/Productivity/Profitability • Resource use/exhaustion (materials, energy, water) • Finances • Production/consumption patterns • Developmental economics • Markets/commerce/trade • Accountability	• Policy/Administration • Products and services: transport, ecoproducts and services, Life Cycle Assessment (LCA) • Pollution/Accumulation of toxic waste/Effluents • Biodiversity • Resource efficiency/eco-efficiency/cleaner production • Climate change: Global warming/Emissions/Acid rain/Ozone depletion • Resources use: depletion and conservation of materials, energy, water • Desertification, deforestation, land use: erosion, soil depletion • Alternatives: energy, technologies	• Demography/Population • Employment/Unemployment • Poverty • Bribery/corruption • Equity/Justice • Health • Politics • Education and training • Diversity and social cohesion • Culture and religion • Labour/Human rights • Peace and security • Work/life balance
	Cross-cutting themes • People as part of nature/Limits to growth • Systems thinking/application • Responsibility • Governance • Holistic thinking • Long term thinking • Communication/Reporting • SD statement • Disciplinarity • Ethics/Philosophy • Transparency	

Source: (Lozano and Young, 2013)

into their professional life (Carew and Mitchel, 2008; Peet et al., 2004). Conversely, embedding SD as a concept within regular courses is a better alternative for raising student awareness of, and responsibility for the environment and their societies (Lozano and Peattie, 2009).

In addition to the two sustainability-focused courses, a 2008 Self-Study Report suggested that instructors believe that sustainability was addressed broadly by CEE courses. In the report prepared for the Accreditation Board for Engineering and Technology (ABET), instructors rated the extent (high, medium, low, or not at all) to which their courses contributed to students "receiving a broad education and knowledge of contemporary issues necessary to understand the impact of civil engineering solutions in a global, social, and environmental context" (Georgia Tech, 2008). Overall, of the 37 courses included in the report, nearly half were cited as "highly" contributing to this sustainability-related educational outcome (see Watson et al., 2013). However, the results may not portray an objective or complete picture of sustainability embedding since they came from instructors' unsubstantiated self-ratings of their classes. Additionally, these might have been affected by the instructors' potential different conceptions of sustainability (see Carew and Mitchel, 2008), which may further their bias their judgments about their own courses. As a result, a more systematic evaluation of the CEE curriculum was needed.

3.2. Assessment of curricula contribution to sustainable development

Several tools have been developed, or modified, to assess SD in universities: e.g. the Auditing Instrument for Sustainable Higher Education (AISHE) (Roorda, 2001), the Graphical Assessment for Sustainability in Universities (GASU) tool (Lozano, 2006), the Environment Sustainability Assessment Questionnaire, and the Environmental Management System Self-Assessment (Shriberg, 2002). However, many of them are focused mainly on improving the sustainability of campus operations (Lozano and Peattie, 2011). One of the few tools focusing specifically on curricula is the 'Sustainability Tool for Assessing UNiversities' Curricula Holistically' (STAUNCH®), which is aimed at helping universities assess, in a holistic and systematic way, the contribution of their curricula to SD (Lozano, 2010; Lozano and Peattie, 2011).

The STAUNCH® system[2] was developed in 2007 (for a more detailed explanation of the STAUNCH® system refer to Lozano, 2010; Lozano and Peattie, 2009, 2011), and updated in 2010 (see Lozano and Young, 2013 for details). It is aimed at assessing university curricula beyond the current emphasis on anecdotal evidence, and non-comparable *ad hoc* reviews. STAUNCH® relies on the explicit published course aims and outlines as a data source. This means that all the necessary information is (or should be) easily accessible, but it also means that the accuracy of the results depends on the accuracy/specifics of the published information. SD education delivered in the classroom but not reflected in the course documentation will not be captured (Lozano, 2010b; Lozano and Peattie, 2011).

The assessment is done on the course descriptors, or syllabi. It has two objectives: (1) to assess systematically how a university's curricula (courses, degrees and schools) contributes to SD (*i.e.* the SD issues' coverage, depth, and breadth); and (2) to facilitate consistent and comparable auditing efforts capable of handling a large quantity of data, and its application across multiple institutions.

STAUNCH® is based on two combined equilibria: firstly, cross-cutting theme issues (such as Holistic thinking, and SD statement (see Table 2)), which are considered to be those that integrate economic, environmental, and social dimensions; and secondly, the SD contribution, which is calculated using formulae that look for the balance among the four dimensions, taking into consideration their strengths.

Two of the key points in the assessment reports are: (1) the level of contribution, indicating the 'breadth' and 'depth' of coverage of sustainability issues (the higher the contribution's value the better the balance amongst economic, environmental, social, and cross-cutting dimensions); and (2) the percentage of courses

[2] To obtain information about the use and licensing of STAUNCH® refer to www.org-sustainability.com/STAUNCH®.

Table 3
SD Contribution and qualitative levels.

Hypothetical degree	Contribution	Level
LU001	0.00	None
LU101	0.01–0.67	Very low
LU201	0.67–1.29	Low
LU301	1.30–1.99	Medium
LU401	2.00–3.50	High
LU501	>3.50	Very high

contributing to SD, given by the number of courses that relate to SD, divided by the total number of courses in each degree. Table 3 provides an illustration of this, as well as the qualitative grading level.

STAUNCH® is aimed at helping universities assess the depth and breadth of their SD-related curricula in a holistic and systematic way to produce standardized and comparable results. Its results provide a 'snapshot' of how SD is currently being addressed within a university. Its reports detail the percentage of courses currently addressing SD, and their balance among the conventional dimensions of SD (economic, environmental, and social) plus those themes that cut across them. This information offers the possibility to detect whether SD is integrated across the curricula, or is being broken down into individual issues to be addressed as a portfolio throughout the curricula. The STAUNCH® 2010 update includes in its calculations the number of credits, and the number of students enrolled in the modules. It also features four new graphs (pie graphs on the indicator coverage for the economic, environmental, social, and cross-cutting themes) to help recognize the criteria that are being addressed, and those that are not. These can help to stimulate discussions with directors of learning on how to better incorporate sustainability into the curricula, and to help the institution to better align with the Decade of Education for Sustainable Development (DESD) (UNESCO, 2005).

STAUNCH® has been used by a number of universities, such as: Cardiff University, UK (refer to Lozano, 2010; Lozano and Peattie, 2009, 2011); University of Leeds, UK (see Lozano and Young, 2013); Monterrey Tech, Mexico; Worcester University, UK; and, through Higher Education Funding Council for Wales (HEFCW) funding, by the other 11 Welsh universities.

STAUNCH® was used to assess the syllabi for 44 undergraduate CEE courses. Each of the syllabi was examined by the second author on the current paper, who has assessed more than 10,000 courses contribution to sustainability.

3.3. Student perceptions surveys

Two surveys were developed and administered in paper format to seniors (students in their final year) in CEE capstone design courses to gain insights into their perceptions of undergraduate sustainability education. The surveys were developed using expert-derived survey design principles (see Alreck and Settle, 1995; Babbie, 1990; Weisberg et al., 1996). These were, as suggested by Rogers and Gotkas (2010) and St. Clair and Baker (2003), reviewed by the Office of Assessment and Institutional Review Board at Georgia Tech to ensure proper format and readability.

Students enrolled in the Spring 2012 CEE capstone design course were invited to complete the Student Curriculum Survey, which prompted students ($n = 82$) to use a seven-point scale to rank the extent of coverage of each of the STAUNCH® criteria by their CEE courses (1 = not at all, 7 = to a great extent). In addition, students were asked to rank the top five CEE courses in which they learned the most about sustainability. Convenience sampling (see MacCormack and Hill, 1997) was used, since the survey was only administered in one of the two 2011–2012 CEE capstone courses. This sample was considered to be representative, since previous work highlighted that few differences related to sustainability knowledge and educational experiences exist between students from the two semesters (see Watson, 2013).

As part of an extended Student Sustainability Survey ($n = 153$) (see Watson et al., 2013), students were asked to rate the overall quality of CEE sustainability education (excellent, good, average, marginal or poor), as well as use a seven-point scale to indicate the importance (1 = not at all important, 7 = extremely important) of implementing several strategies for improving CEE sustainability education. The proportion of students indicating a response of six or seven (π_{6-7}) was compared to the proportion of students providing a response less than six. Convenience sampling was again used, although responses from nearly 75% of the graduating population was obtained.

One key assumption was that students possessed the sustainability knowledge needed to accurately assess curricula content and quality. For the current study, students had completed a sustainability-focused course and almost 50% of a larger sample of seniors at Georgia Tech indicated that they were 'extremely confident' in their abilities to discuss SD (see Watson et al., 2013).

4. Results from the curricula assessment and the student perception surveys

This section presents the results from the STAUNCH® assessment of the CEE curriculum at Georgia Tech, and from the student perceptions surveys.

4.1. STAUNCH® assessment results

The STAUNCH® results showed that most CEE courses contributed mainly to the environmental dimension of sustainability (62%), with lower contributions to the cross-cutting (24%), economic (12%) and social (3%) ones. The contribution of courses to sustainability was 1.36, which is classified as a "medium" contribution (Table 3). This was mainly due to the course overemphasis on the environmental dimension. The strength of the contribution was also "medium" (1.39). The strength metric could be improved if the sustainability criteria (Table 2) were covered more in-depth.

Although most courses exhibited "low" or "very low" contribution (refer to Table 3 for the contribution range), several courses had scores within the "medium" range or higher (Table 4). For instance, the Construction Engineering and Management course exhibited a high contribution (3.33) through consideration of all sustainability dimensions. Civil Engineering Systems and Environmental Systems Design also demonstrated high contribution scores

Table 4
CEE courses with medium or high contributions to sustainability education (in percentages).

	Contribution	Economic (%)	Environmental (%)	Social (%)	Cross-cutting (%)
Construction Engineering and Management	3.33	40	20	20	20
Civil Engineering Systems	2.00	14	14	0	71
Engineering Systems Design	2.00	33	33	0	33
Sustainable Engineering	1.44	8	46	8	38

(2.00), although the results from the curriculum assessment did not show any contribution to social issues. This was due to the course content not explicitly mentioning any social issues. Finally, Sustainable Engineering showed a medium contribution (1.44), with the syllabus suggesting that all four dimensions are addressed in some capacity.

Despite the emphasis on environmental sustainability, a variety of sustainability topics were emphasized in undergraduate CEE courses (Figs. 1–4). Almost all environmental topics were addressed (with the exception of resource efficiency/eco-efficiency). The environmental criteria with the highest coverage were resource use (22%), pollution (17%), products/services (14%), and land use (14%).

The results also show the coverage of the cross-cutting dimension, with disciplinarity (45%) and SD statements (22%) being the most addressed. Within the economic dimension, only three of the seven criteria were addressed – finances (56%), resource use (33%), and production/consumption patterns (11%). Most criteria within the social dimension were absent, except human rights, employment, and equity/justice accounted for equal parts (33%). Although the results indicated an emphasis on the environmental dimension, it may be possible that classroom activities and interactions addressed the other dimensions, or may have not dealt with some explicitly mentioned on the syllabi.

4.2. Student surveys results

The student surveys results indicated that CEE courses most extensively address the cross-cutting themes and the environmental dimension (Table 5). The results show that 45% of student responses indicated that cross-cutting and topics were incorporated "to a great extent" within the curriculum (responses of 6–7 on seven-point scale), especially long-term thinking, SD, and communication. In addition, 37% of responses showed that environmental topics were significantly integrated into the curriculum, including pollution, climate change, and resources use. The economic and social concepts were indicated to be the least incorporated into CEE courses, with related topics earning scores of 6 or 7, *i.e.* only 22 and 16%, respectively.

A majority of students classified the sustainability content as "very good" (46.4%) or "average" (32.7%), while only a few students (13.1%) provided responses of "excellent". Many students indicated that it was very important to improve sustainability education through providing more guidance on how to apply sustainability concepts to design ($\pi_{6-7} = 59.5\%$), offering more courses that focus on sustainability concepts ($\pi_{6-7} = 51.0\%$), providing more opportunities for students to discuss sustainability topics ($\pi_{6-7} = 45.3\%$), and adding more sustainability concepts into existing classes ($\pi_{6-7} = 45.1\%$). Thus, despite the overall positive student assessments, student responses depicted the need to improve sustainability education.

Additionally, the students were asked to rank the top five courses in the CEE curriculum that they viewed as most addressing sustainability (Table 6), where the 1st choice received a score of 5 and the 5th choice a score of 1. The students ranked 21 different courses as having incorporated sustainability concepts. Based on the total scores, the students indicated that Civil Engineering Systems and Capstone Design were the ones that had most content on sustainability. However, both of these courses were compulsory for all CEE students, so it may be possible that their high scores were a result of the large number of enrolled students. Based on the total scores normalized by number of enrolled students during the 2010–2011 academic year, the course Environmental Impact Assessment had the highest contribution to sustainability, followed by Civil Engineering Systems and Capstone Design were ranked in the top three.

4.3. Comparing the results from curricula assessment and student perceptions surveys

The results from the curricula assessment and student perception surveys helped to answer this paper's research questions.

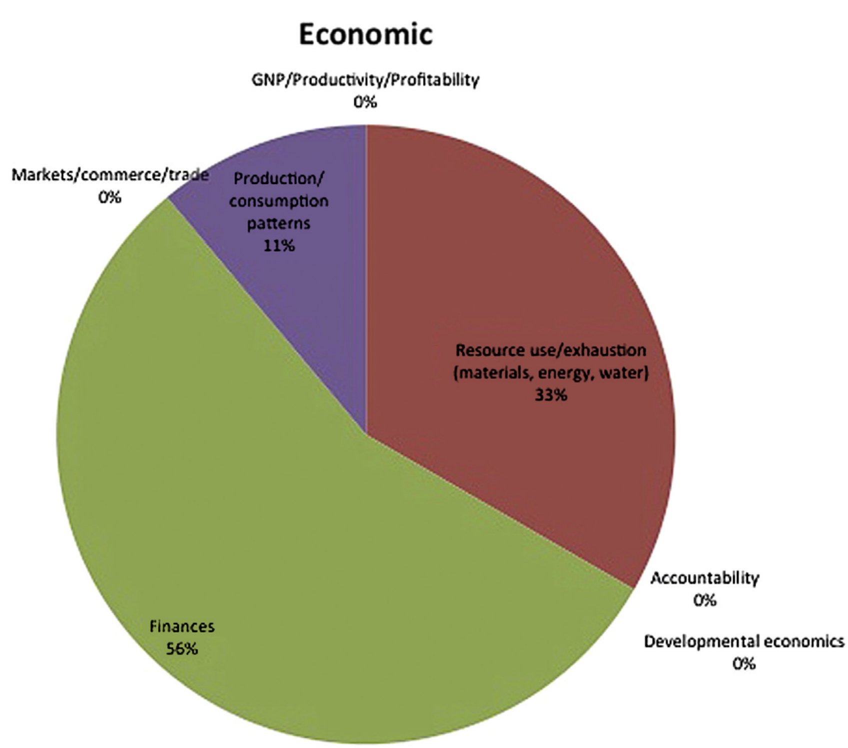

Fig. 1. Results from STAUNCH® criteria coverage of the economic dimension of the CEE undergraduate curriculum at Georgia Tech.

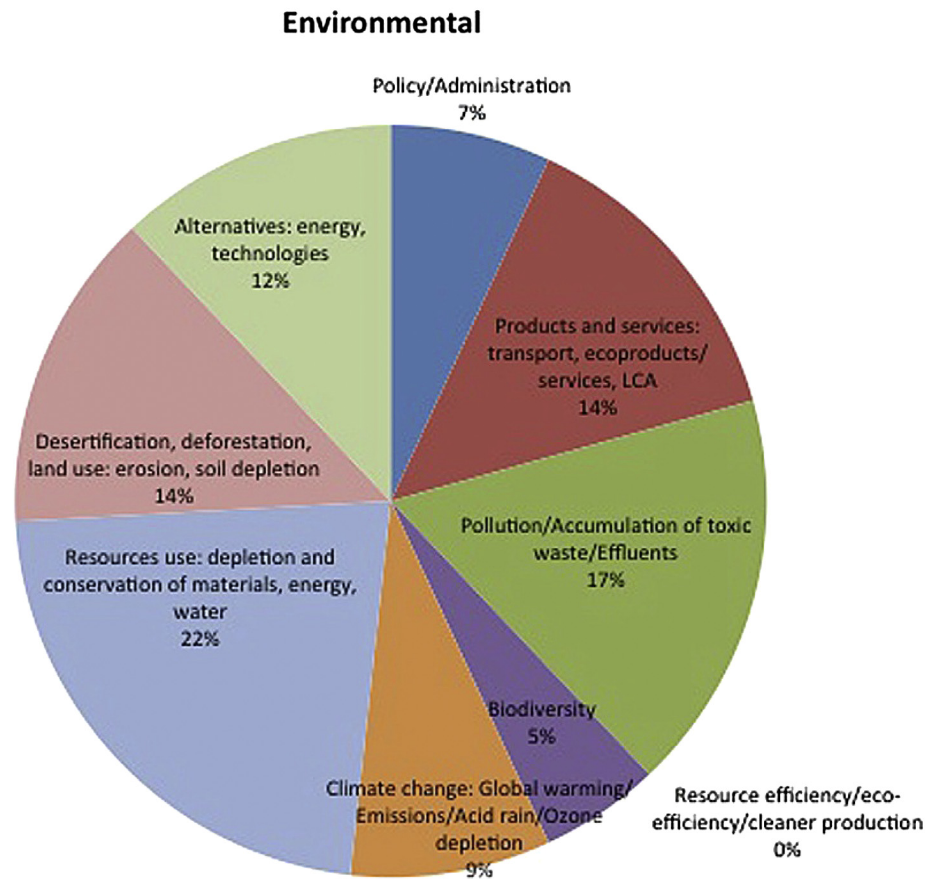

Fig. 2. Results from STAUNCH® criteria coverage of the environmental dimension of the CEE undergraduate curriculum at Georgia Tech.

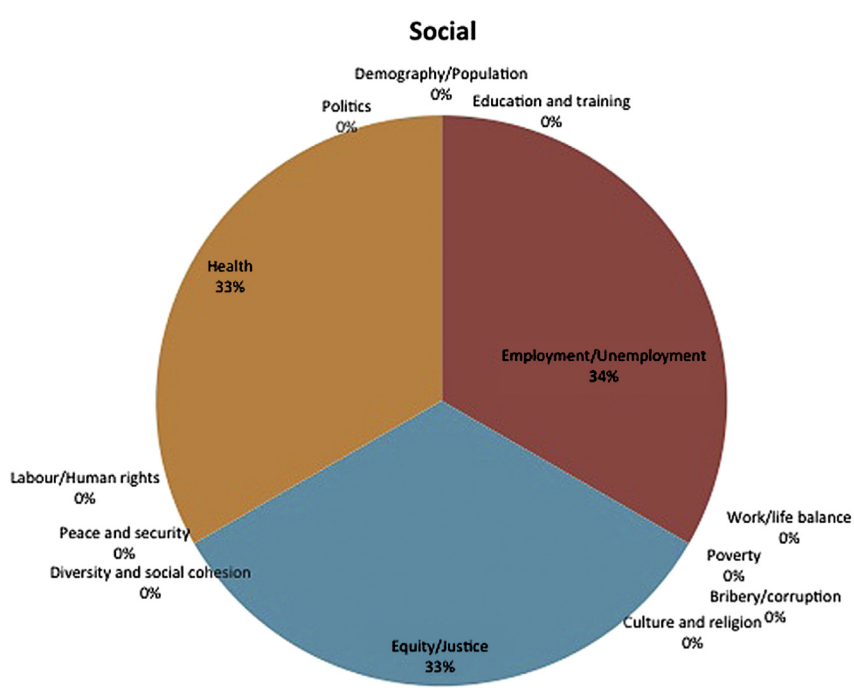

Fig. 3. Results from STAUNCH® criteria coverage of the social dimension of the CEE undergraduate curriculum at Georgia Tech.

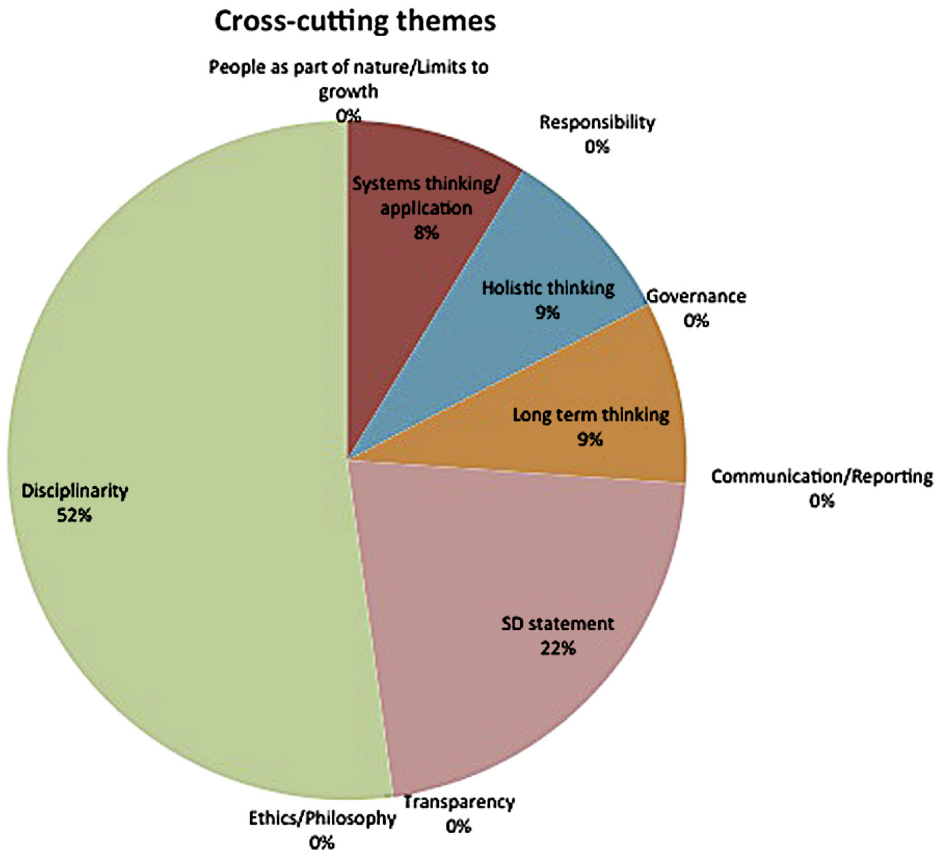

Fig. 4. Results from STAUNCH® criteria coverage of the cross-cutting themes of the CEE undergraduate curriculum at Georgia Tech.

A number of similarities and differences were found between key courses identified by the STAUNCH® assessment and the student perceptions surveys, which helped answer the first research question (*What is the extent of integration of sustainability across engineering curricula?*). The STAUNCH® results showed that the main focus was on the environmental dimension in CEE courses, followed by the cross-cutting themes. The contribution of the curriculum to sustainability education was characterized as "medium", in part due to the low coverage of the economic and social dimensions.

The two student surveys were used to help answer the second question (*What are student perceptions of the contribution of courses to sustainability?*). The responses indicated that the cross-cutting themes were the most covered, followed closely by the environmental dimension. Nearly half of students rated the overall quality of the curriculum as "very good." A number of courses were identified by the students as contributing significantly to sustainability education. They also indicated that social issues were being covered in the classroom, although they were not present in the syllabi, as indicated by the curricula assessment results.

The final question of this research (*What can be learned from integrating curricula assessment and student perceptions of sustainability integration?*) was aimed at the comparing and contrasting the results from the curricula assessment and the student perceptions survey. The STAUNCH® assessment and student surveys results concurred with regards to sustainability dimensions most integrated into the CEE curriculum. Overall, both methods showed that the contribution was mainly focused on the environmental dimension and the cross-cutting themes. The identification of key concepts and criteria most incorporated into the curriculum was fairly similar for both methods, although there were some discrepancies (Table 7). Within the economic category, finances, resource exhaustion, and production/consumption patterns were addressed. However, accountability was absent from the STAUNCH® results, while students indicated this topic to be the second most emphasized economic topic. Within the environmental dimension, both assessments highlighted that resources use, pollution, and products/services were commonly discussed in the courses. The student surveys responses highlighted that land use topics were less emphasized than proposed by STAUNCH®, while climate change topics were more extensively addressed. Both

Table 5
Student rankings on the extent of incorporation of STAUNCH® criteria into the CEE curriculum at Georgia Tech (only top five highest-rated criteria shown) ($n = 82$).

Economic topics	π_{6-7} (%)	Environmental topics	π_{6-7} (%)
Resource exhaustion	38	Pollution	54
Accountability	30	Climate change	49
Finances	24	Resources use	45
Developmental economics	18	Products/Services	39
Production/consumption patterns	17	Alternatives	38
Overall[a]	22	Overall[a]	37

Social topics	π_{6-7} (%)	Cross-cutting topics	π_{6-7} (%)
Education	41	Long-term thinking	65
Health	27	SD	59
Politics	21	Communication	56
Population	18	Responsibility	55
Diversity	17	Systems thinking	54
Overall[a]	16	Overall[a]	45

[a] Calculated as (Number of 6–7 rankings within dimension/total number of rankings within dimension) multiplied by 100.

Table 6
Courses with highest contribution to sustainability, according to student perceptions[a] ($n = 84$).

Rank	By raw score[b]	By normalized score[c]
1	Civil Engineering Systems	Environmental Impact Assessment
2	Capstone Design	Civil Engineering Systems
3	Environmental Engineering Principles	Capstone Design
4	Environmental Engineering Systems	Air Pollution Engineering
5	Environmental Impact Assessment	Environmental Engineering Systems

[a] Students responded to prompt: "Think about all the courses you have taken in civil and environmental engineering (CEE). Which courses do you believe addressed sustainability? Rank the top 5 courses which addressed sustainability, with#1 being the course that most addressed the topic. You do not have to fill in all five spaces".
[b] Students ranked the top five CEE courses contributing to sustainability education. Courses ranked as first received a score of five, while courses ranked as fifth received a score of one. Scores were summed for each course.
[c] Raw score for each course was divided by the number of students enrolled in that course during the 2011–2012 academic year to eliminate any unfair advantage of courses with required or high enrollment.

results showed that SD statement, systems thinking, holistic thinking, and long-term thinking were incorporated into the curriculum. Although STAUNCH® was not designed to detect the emphasis on communication and responsibility, the surveys showed that students were exposed to sustainability in CEE courses. The biggest differences were for the social dimension, in which the top five concepts identified by students were not present in the STAUNCH® results. The discrepancies may likely result from course syllabi not accurately capturing all aspects of classroom activities.

Although the STAUNCH® results indicated that the curricula were mainly contributing to the environmental dimension, the student surveys results indicated that many of the courses were highly ranked on sustainability (see Table 6). Two possible explanations for this could be: (1) the course syllabi and the delivery of the content were considerably different, where the former focused on the environment and the latter on broader sustainability; or (2) the perception of the students about sustainability was biased towards the environmental dimension, and sustainability, therefore, had an environmental connotation.

The courses Environmental Impact Assessment, Air Pollution Engineering, and Environmental Engineering Systems had "very low" or "low" contribution scores, because the syllabi only provided evidence that environmental topics were discussed in class. However, these courses were consistently ranked highly based on their overall sustainability content. While this may simply suggest discrepancies between course syllabi and classroom instruction, it is possible that students fail to grasp the multi-dimensional nature of sustainability, as has been suggested by other authors (e.g. Segalàs, Ferrer-Balas, & Mulder, 2010; Walshe, 2008).

The STAUNCH® assessment and student perceptions surveys indicated that although there was relatively good contribution to sustainability at the CEE, there is still potential for improvement. The STAUNCH® contribution and strength results were in the medium range. This substantiates the CEE's intentional efforts to expose students to sustainability (Georgia Tech, 2008). However, it indicates that additional reforms could further promote student learning. Similarly, only 13% of students indicated that the overall quality of sustainability education was excellent, and many students supported various reform efforts to improve sustainability integration. Overall, the results show that CEE has been advancing towards educating sustainability-conscious engineers.

5. Discussion

From the results it is possible to propose three recommendations for a better integration of sustainability into engineering undergraduate curricula. First, as indicated by different authors (see Ceulemans and De Prins, 2010; Peet et al., 2004), incorporating sustainability concepts broadly within existing courses in conjunction with technical content (horizontal integration) may encourage students to view sustainability in a systemic and holistic manner, as well as promote sustainability in their professional practices. With 61% of all courses incorporating some aspect of sustainability, CEE at Georgia Tech has made significant efforts to adapt the horizontal integration strategy. In addition, as with the studies at UBC (2009) and Shandong University (Yuan and Zuo, 2013), CEE students showed interest in sustainability. However, as with the Chinese students (Yuan and Zuo, 2013), CEE students were reluctant to have sustainability integrated sustainability into existing classes. As a result, administrators and instructors may need to be aware of potential student resistance when attempting to broadly incorporate sustainability into traditional courses.

Second, the incorporation of sustainability content across a curriculum must be balanced among all sustainability dimensions (as indicated by Davidson et al., 2007). However, the results of the STAUNCH® and student surveys indicated that the main focus was on environmental dimension, as compared to the economic and social dimensions. Similarly, many stakeholders, including students and university leaders from a variety of institutions, tend to focus on the environmental dimension of sustainability (as discussed by Barth and Timm, 2011; Kagawa, 2007; Segalàs et al., 2010; Tuncer, 2008; Wright and Wilton, 2012; Yuan and Zuo, 2013). Therefore, it is necessary to have degrees where the different courses provide an integrated balance of the sustainability dimensions.

Third, a "stronger" integration of balanced sustainability concepts into courses is needed. For the case of Georgia Tech, where the strength was medium (1.39), efforts should be made to demonstrate more in-depth connections between technical and sustainability content. Perhaps by using active and experiential pedagogies (e.g. project-based learning, case study, evaluation, role-playing) as posited by Segalàs et al. (2010) to encourage integration of sustainability concepts into students' knowledge networks.

This paper shows that the STAUNCH® and the student perceptions surveys can be useful when curricula assessments. Both research methods corroborated the CEE claims that sustainability

Table 7
Summary of top five most emphasized topics within the CEE curriculum according to both STAUNCH® assessment and student surveys.

	STAUNCH® results	Student surveys results
Economic dimension[a]	Finances, Resource use, Production/consumption patterns	Resource exhaustion, Accountability, Finances, Developmental economics, Production/consumption patterns
Environmental dimension	Resources use, Pollution, Desertification, Products/services, Alternatives	Pollution, Climate change, Resources use, Products/services, Alternatives
Social dimension[a]	Employment, Equity, Health	Education, Health, Politics, Population, Diversity
Cross-cutting themes	Disciplinarity, Sustainable development, Systems thinking, Holistic thinking, Long-term thinking	Long-term thinking, Sustainable development, Communication, Responsibility, Systems thinking

[a] STAUNCH® results only indicated that three topics from these dimensions were addressed in the curriculum.

has been integrated into the curriculum (see Georgia Tech, 2008); nonetheless both methods also highlighted the capacity for further improvement. The results from the two approaches indicated that there was a strong focus on the environmental dimension. However, some slight discrepancies were identified related to the specific topics that are covered in CEE courses, especially within the social dimension, since the curriculum assessment did not show any contribution to these issues, but the students indicated that social issues were being covered in class. This shows that SD education delivered in the classroom is not always reflected in course documentation (as posited by Lozano, 2010; Lozano and Peattie, 2011). Thus, the STAUNCH® assessment and perceptions surveys may be used to assess the overall status of a curriculum's contribution to sustainability. This combination can provide a more detailed and holistic picture of contribution to sustainability of a curriculum.

Incorporating sustainability into undergraduate engineering curricula (with one or both of the curricula assessment methods used in this study) is critical. This can result in reforms that expose students to sustainability-related content in the classroom, lead to pro-sustainability related actions, and foster more sustainability-conscious engineers.

6. Conclusions

This paper presents a study focused on evaluating sustainability education in CEE at Georgia Tech. It integrates two growing fields in HESD, curricula assessment for sustainability and stakeholders' ESD perceptions and attitudes. After assessing the contribution to sustainability content of the curriculum based on STAUNCH® assessment and examination of student perceptions, several conclusions can be made:

1. The results show that sustainability is being broadly integrated into the curriculum, with over 60% of CEE courses incorporating one or more related topics;
2. Despite this broad integration, the curriculum significantly overemphasizes the environmental dimension, while grossly underemphasizing the social dimension;
3. The "medium" contribution and strength curricula assessment results indicate that there have been efforts to incorporate sustainability into the courses, although there is potential for further improvements; and
4. Despite some discrepancies, the student perceptions concur with the STAUNCH® assessment, which indicates that, in general, .the syllabi and the activities in-class are congruent in teaching sustainability.

This paper shows that when designing an engineering curriculum, it is necessary to ensure that the different courses are developed or modified to be complementary and provide a more holistic and complete contribution to sustainability (including the economic, environmental, and social dimensions, as well as the cross-cutting themes).

Integrating curricula assessment and student perceptions can provide a more holistic overview of the contribution of courses and degrees to sustainability. These two approaches can help to detect discrepancies between sustainability content in the syllabus and sustainability teaching in the classroom. The approaches can help university leaders better plan educational changes to devise curricula reforms to promote sustainability learning and students to reflect upon the topic, as well as fostering their engagement in such changes. They can also help bridge the gap between the activities being done at the university to foster sustainability and what student perceive to be achieved.

It is imperative that sustainability topics be discussed and applied extensively, strongly, and in-depth in courses to ensure that students understand and are able to apply sustainability in their future professional lives. It is necessary to develop higher education curricula that can educate engineers (and non-engineers) in a more holistic way to help the transition towards more sustainable societies.

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