Applied Sustainability Education with a Systems Science Emphasis at a STEM University

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1 Introduction

Universities have a historic and continuous role as urban centers of education, research, and the arts: they are explicit lynchpins of culturally and technologically strong cities and societies. A fundamental university role at local through international scales is the development of innovations in any number of human endeavors (cf. Cortese 2003; Aber et al. 2009; Calder/Dautremont-Smith 2009). Gregory Trencher, Masaru Yarime, Kes B. McCormick, Christopher N. Doll and Stephen B. Kraines provide evidence for an “… emerging, new mission for the university”, where universities provide unique resources to local government, industry and NGOs to advance sustainable transformations of cities or regions (cf. Trencher et al. 2014). Over time, the impacts of such innovations (technological or social or both) feed back into academic curricula with the emergence of new courses and programs reflected in expanded sustainable practices on campus and beyond (cf. Sterling/Huckle 2014).

In support of the evolving role of universities and innovation, high school students in the U.S. are displaying an increased interest in sustainability degree programs and careers (cf. AASHE 2009; Chronicle of Higher Education, 2010; Princeton Review 2015). For example, over 100 major, minor, and certificate programs were created in 2009 on energy- and sustainability-focused programs in the U.S. (cf. Schmit 2009). More than 25% of incoming freshmen considered “becoming involved in programs to clean up the environment” as essential or very important (cf. Chronicle of Higher Education 2010), an increase of > 50% from five years prior. A survey of 16,000 students and parents found that 66% were interested in college sustainability efforts and 24% said such information would “very much” impact application or attendance decisions (cf. Princeton Review 2011).

A survey of 260 U.S. university administrators on the availability of “interdisciplinary environmental degrees” included the term sustainability and concluded “the last two decades have seen extraordinary growth in the creation of new educational programs” (Vincent 2009). Note that these programs often include sustainability certifications and specializations. Minor and major academic programs are also increasing
in occurrence but require more resources. University sustainability programs of many varieties can work to integrate academics and campus operations (cf. Parnell et al. 2014) and research (cf. McMillin 2009).

The steady increase in the national interest in sustainability is reflected in the increases in university bachelors degree offerings, with over 70 B.S. or B.A. degree titles including the term sustainability available in the U.S., the majority appearing since 2000. University investments in sustainability are based in part on employer demand for interdisciplinary systems thinkers, the competitive advantages of increased student recruitment, the potential for reduced operating costs and the desire to innovate (cf. Princeton Review 2015).

Many sustainability degrees are Bachelor of Arts and are not at institutions that historically specialize in Science, Technology, Engineering, and Mathematics (STEM) content areas. Adjacent to NASA’s Kennedy Space Center in coastal east Florida, Florida Institute of Technology (F.I.T.) began new academic sustainability initiatives in 2010 which imbedded work on campus and community best practices. A minor program began in Fall 2010 and a Bachelor of Science major in 2013/14 that introduced new courses specific to system science and sustainability, and project design and management, in addition to > 100 interdisciplinary elective courses. Over two thirds of the undergraduate population at F.I.T. are in the College of Engineering or College of Science. STEM universities offering named sustainability bachelors degrees are not common but include Rensselaer Polytechnic Institute and Rochester Institute of Technology in the northeastern U.S.

In Florida and the southeast U.S., the Sustainability Studies bachelors program at F.I.T. is one of the first of its type among STEM universities. A preliminary case study is constructed here from recent initiatives at this university with a focus on:

(a) the diversity of interests among academic programs in differing colleges,
(b) the use of system sciences in sustainability education, and
(c) campus and community green initiatives as curricular objectives.

Primary program development trends are considered with a focus on optimizing responses to system complexities that arise when building university sustainability initiatives.

2 Academic Sustainability

2.1 Sustainability Programs

At least 72 U.S. universities offer bachelors degrees with the words Sustainable or Sustainability in the degree title. 43 of these degrees are B.S. and 29 are B.A. based
on reviews conducted through early 2014. The most common degree titles included Sustainability Studies, Environmental Sustainability, and Sustainable Development. Many degree titles also reflect specific disciplines such as Sustainable Business or Sustainable Agriculture. Sustainability Studies degrees are offered in both B.S. and B.A. programs. Online sustainability majors, certificates, and specializations are also offered by some U.S. universities. At least 50 foreign universities offer bachelor-equivalent sustainability degrees in various languages via on-site or online programs.

Of almost 100 colleges and universities in Florida, <25% currently have formal minor programs in sustainability, and <10% have named majors in sustainability. There are various certificates and specializations in sustainability and related fields in Florida colleges and universities as elsewhere. The numbers of these types of programs can be sizeable compared to formal major and minor academic programs which are recorded on final transcripts.

The initiation of a Sustainability Minor program in 2010 and a Bachelor of Science in Sustainability Studies major program in 2013 at F.I.T. have added four new courses specific to sustainability, systems science, and green project design to date. Interdisciplinary courses from four concentration categories are also required for the minor and major programs: Business, Environmental Sciences, Technology and Engineering, and Social Sciences. Cross-campus integration of sustainability into other programs is advanced by a sustainability module within the University Experience course required of freshmen in all majors and a University Sustainability Council with multiple faculty representatives from all colleges and primary administrative departments on campus.

Between academic years (AY) 2010/11 and 2014/15, over 60 students graduated with a minor in sustainability (see Figure 1). By the end of AY 2015/16, over 80 students total will have graduated with the minor or the new major (AY 2015/16 data is projected from Dec. 2015 petition-to-graduate paperwork). Overall, 25% of the total graduates are from outside of the U.S. with 12 total countries represented and six graduates each from India and the Middle East. Since AY 2010/11, the program has steadily attracted more students with 20 or more students graduating in three of the last four academic years, with the highest numbers in the last two years (see Figure 1). This is more than two times the next most popular minors on campus, of 30 total minor programs at F.I.T.

A major attribute of the sustainability minor program is the diversity of different majors represented in the student population. Figure 2 shows the total number of graduates from each college for the first six academic years. Students from over 20 different majors from the five colleges on campus will have earned the sustainability minor by the end of AY 2015/16. The College of Engineering will have the highest number of graduates to date with 38 students (see Figure 2). The College of Science will have 24 graduates during this period. The Colleges of Business, Psychology and Liberal Arts, and Aeronautics will have 12, 5, and 3 graduates, respectively, by the end of AY 2015/2016.
Figure 1: Graduation Totals by Year for the Sustainability Minor and Major Programs, Academic Years 2010/11–2015/16, Florida Institute of Technology

Sustainability Minor & Major Graduates
Academic Years 2010-2016

Figure 2: Graduation Totals by College for Sustainability Minors and Majors, F.I.T., Academic Years 2010/11–2015/16

COA: College of Aeronautics
COE: College of Engineering
COPLA: College of Psychology and Liberal Arts
COS: College of Science
COB: College of Business

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The 38 graduates from the College of Engineering are represented by ten majors (see Figure 3). The majority of these students, 15, are from the Construction Management program. The Department of Marine and Environmental Systems is represented by 10 total sustainability minors, from Environmental Science, Ocean Engineering, and Oceanography majors (5, 3, and 2 graduates, respectively). The Civil Engineering and Mechanical Engineering majors had 7 and 2 sustainability minors, respectively. In an important reflection of the continued dispersal of inter-disciplinary sustainability at

Figure 3: Graduation Totals for Sustainability Minors, College of Engineering, F.I.T. Academic Years 2010/11–2015/2016

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<thead>
<tr>
<th>Year</th>
<th>Major</th>
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<tr>
<td>2010-2011</td>
<td>Mechanical Engineering</td>
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<td>2011-2012</td>
<td>Civil Engineering</td>
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<td>2012-2013</td>
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<td>Construction Management</td>
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<td>Environmental Science</td>
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<td>Oceanography</td>
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<td>2013-2014</td>
<td>Construction Management</td>
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<td>Environmental Science</td>
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<td>2015-2016</td>
<td>Civil Engineering</td>
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<td>Electrical Engineering</td>
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Based on the results from the minor program and scoping of the growing number of U.S. universities with bachelors programs in sustainability (cf. Princeton, Review, 2011), F.I.T. launched a Bachelor of Science program in Sustainability Studies in Fall 2013. The first graduate of the new major program was in Dec 2015, with 3 more stu-
students graduating by the end of AY 2015/16 (see Figure 4). The program curriculum takes advantage of F.I.T.’s existing STEM strengths and includes two years of core science preparation with one year each required of calculus, physics, chemistry and biology (all courses are 4, not 3, credit hours including laboratory components). Juniors and seniors have > 100 intermediate and advanced sustainability elective courses available including a range of economics and social sciences courses to enhance the transfer of science and technology innovations into corporate and government realms. In total, Sustainability Studies majors take a minimum of 6 economics/business courses and up to 12 courses in some cases.

2.2 Systems Science Education for Sustainability

To further examine hierarchical system dynamics within and among natural, social, and economic capital, additional sustainability courses have been launched with more in development. The emphasis includes systems sciences and green project management with new upper level courses such as Systems, Governance and Sustainability (ISC 3250) and Sustainable Project Design (ISC 3999). The prerequisite for both of these courses is Introduction to Sustainability (ISC 1500) which uses “Thinking in Systems: A Primer” (cf. Meadows 2008) as a textbook to introduce systems complexity and sustainability using stock-flow dynamics and feedback to explain non-linear networks and long-term system behaviors. Approximately 160 students from > 20 majors and all F.I.T. colleges have taken this course through AY 2015/16.

The applied academic goals in ISC 1500 are to learn and explore combinations of tools that advance innovations in sustainability among complex socio-economic and environmental systems. The introductory focus is on five interconnected mega-systems developed from class notes that drive most of the Earth’s most challenging sustainability issues: Population and Consumerism; Natural Capital and Biodiversity; Energy and Climate; Economics and Business; and Communications and Societal Dialogue, collectively the Five Guerillas.

Primary components of systems science in ISC 1500 include stocks and flows, feedback loops, limits, response delays, orderly and chaotic perturbations, system traps, shifting dominance of feedback, tipping points, and post-transition system behaviors. At intermediate levels in ISC 3250, tools such as complexity theory, risk-based decision assessment, resiliency, behavioral economics, political ecology, and social network analysis are detailed (cf. Espinoza/Walke 2011). Practical applications in real-world political systems are emphasized at local through international scales (cf. Lindeman et al. 2015; Worldwatch Institute 2014).

Collectively, best practices in maintaining complex systems through non-equilibrium processes for long term sustainability are examined in integrated courses and through applied projects. Means to identify, measure, adapt and communicate per-
formance indicators of sustainability are queried and compared among government, business, and non-profit systems. The management of emergent properties and other guaranteed surprises is illustrated using resilience science applied to economic, environmental, and social capital examples (cf. Walker/Salt 2006).

3 Campus and Community Sustainability

For both minors and majors in sustainability, the required junior/senior capstone projects use a campus and community classroom model: students develop and manage applied sustainability projects on campus or in the larger city- or county-scale community for applied project management experience. In fall 2014, ISC 3999, a one-credit Sustainable Project Design course, became a prerequisite for the three-credit ISC 4000 for minor students and an original requirement in the major program. Student/staff/faculty teams have worked on issues including campus recycling, LEED building certification, composting, sustainable events, off-campus internships, and major planning processes such as the first campus sustainable transportation plan, stormwater plan, green IT plan, and sustainable purchasing plan. The addition in summer 2015 of a new University Sustainability Office (USO) in Facilities Operations will assist and expand many campus initiatives.

Capstone course projects are structured to generate interdisciplinary and team learning experiences (see Figure 5) and include:

– **Sustainable Buildings:** Many students have implemented best practices in building systems with senior Facilities Operations staff and consultants via work on U.S. Green Building Council certification credits. Many minor students doing building projects were majors in Construction Management and Civil Engineering but some were from diverse majors in the Colleges of Business and Science. Students have worked on all credit categories for LEED certification: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovation. With Facilities staff, this collaboration has helped result in the certification of one LEED Silver building, an outdoor campus swimming complex with new energy and water efficiency design features, and two other LEED buildings, one Certified and one potential Gold. All three of these buildings were evaluated in the New Construction category.

– **Recycling:** Student projects have included dormitory, electronics, and workspace recycling. Planning for more fully integrated projects is being aided by the USO, the Office of Residence Life and staff in specific areas (e.g. the campus library). Best practices will be reinforced by design and implementation of signage with effective messaging by the USO and other Facilities resources, student organizations and the Marketing Office.
Figure 5: Campus and Community Sustainability Groups (Circles) Associated with Applied Sustainability Course Capstone Projects (Boxes), 2012–14, F.I.T.

- **Dining Services**: Further expansion of organic and vegan dining options, new cardboard baler systems, more certified sustainable coffee options, more recycled packaging, sourcing of food waste for composting, and cooking oil to power university vehicles are among the projects undergoing scoping or implementation for on-campus dining options.

- **Land & Water**: Garden clean-ups and invasive plant removal in F.I.T.’s 16 acre Botanical Gardens and wetland are managed by Facilities Operations and aided by on- and off-campus organizations. Enhanced signage on the importance of this watershed to the larger City of Melbourne for stormwater runoff and other functions is being scoped. Students and staff have maintained a vermiform composting system at intervals using waste from the dining hall of the Student Union Building. Rainwater gardens and other stormwater innovations are also being scoped.
- **Sustainable Events**: Diverse best practices in sustainability are increasingly used in event management. Students have worked to bring sustainable practices to campus offices and events including the F.I.T. Conference Services Bureau, International Festival, Woman’s Business Center, and campus Botanical Festival. Students have also worked to bring best practices in sustainability to very large off-campus events including several years of the Melbourne Music Marathon and Ron-Jon’s Beach and Board Festival in Cocoa Beach with many thousands of attendees per event.

- **Community Internships**: F.I.T. students have done internships with local nonprofit organizations for their capstone projects since AY 2011/12. These include multi-year partnerships with NGOs, businesses and governments such as Keep Brevard Beautiful, Smooth Running, and the City of Satellite Beach, respectively. Interns have worked on several initiatives for a major regional watershed NGO, the Marine Resources Council, including the 2014 American Assembly for the Indian River Lagoon, the lagoon health report card, and a green lagoon business certification program.

- **Sustainability Communications**: Messaging and education are fundamental to adoption of best practices for many projects. In the past, student groups, the SGA, and university staff offices have distributed sustainability information across multiple outlets to tell some of the stories that underlie making new sustainability projects sustainable. These efforts are now coordinated largely by the Communications Subcommittee of the University Sustainability Council and other resources.

### 4 Discussion

The first two students to enter the sustainability minor program were majors in Mechanical Engineering and Marine Biology; fitting as these are the two largest majors in the College of Engineering and College of Science at F.I.T. Total minor graduates for AY 2016/17 are conservatively estimated at between 25 and 30, the highest graduate totals to date. The class of May 2017 will exceed 100 total major and minor graduates since AY 2010/11.

It is often said that sustainability is a process and not an end; this certainly applies to the early stages of academic program creation and implementation (cf. Sharp 2002). There are various applied goals and projects that will still take many years to make operational on campus. One priority is expanded integration of sustainability education across academic programs on campus. A sustainability module has been added to the University Experience course required of all freshmen. Over 500 freshman participate in this course annually.
The large Northrup Grumman Design Showcase at F.I.T. in 2013 was won by a team of Construction Management students, three of these four students were also in the Sustainability minor program. The first Sustainability UnderGraduate Academic Research competition (SUGAR) occurred within the 2015 Northrup Grumman Showcase, with the winning project being an internship report on an indicator-based report card on the status of the Indian River Lagoon, a major Florida estuary. Business and Psychology students also presented research on campus vehicle GHG emissions and coastal climate adaptation at SUGAR 2015.

The creation of the new University Sustainability Office will be valuable to numerous facets of campus sustainability including a major focus on energy, water and waste efficiencies. In addition, the University Sustainability Council (USC) with 24 current members is explicitly increasing coordination among staff, faculty and students to advance best practices across the Florida Tech campus. Representatives include senior staff from diverse campus offices, faculty members from all colleges, and student representatives. Broad objectives include:

- Create a forum to plan, resource, and implement best practices in sustainability across academic curricula, campus operations and community outreach.
- Assist development of measurement protocols for campus sustainability systems including GHG emission inventories and energy management, building performance, recycling, and others.
- Coordinate the development of trans-disciplinary curricula in sustainability studies across all colleges.
- Increase performance in best practices following Princeton Review’s Guide to Green Colleges, AASHE’s Sustainability Tracking and Rating System (STARS), LEED building rankings, and other measures.

The U.S. Bureau of Labor Statistics does not have direct data on the number of workers involved in sustainability activities but there is widespread evidence of increasing opportunities for workers trained in a diverse array of sustainability-related position (cf. Hamilton 2012; Princeton Review 2015). The Economic Policy Institute examined in 2012 the private and public sector markets for sustainability-related jobs with these conclusions: greener industries grow faster, states with more developed sustainability policies fared better in the economic downturn, green jobs go far beyond renewable energy, and manufacturing plays a strong role in the green economy (cf. Pollack 2012).

In terms of those doing the hiring, one of the largest studies on CEO opinions of sustainability, Peter Lacy, Tim Cooper, Rob Hayward and Lisa Neuberger surveyed > 700 CEOs and the conclusions imply an increasing demand for sustainability-trained workers (cf. Lacey et al 2010):

- 93% of CEOs believe that sustainability issues will be critical to the future success of their business.
– 91% of CEOs report that their company will employ new technologies to address sustainability issues over the next five years.
– 96% of CEOs believe that sustainability issues should be fully integrated into the strategy and operations of a company (72% in 2007).

The new Sustainability Studies major program at F.I.T., the fourth named bachelors program to date in the state of Florida (with > 80 colleges and universities total), will have its first graduate in the fall semester of 2015. Though still in early stages, the program is catalyzing deeper levels of interdisciplinary study and applied systems science within the structure of the university’s five colleges. We anticipate further advances in interdisciplinary education and sustainability research to be catalyzed by the major and minor academic programs, the USO, the USC, and many other campus and community partners. There are few reasons to conclude that interest in academic and campus sustainability will decline in the near future (cf. earlier citations). The evidence suggests that coordinated sustainability programs at STEM universities can also integrate economics and social sciences to advance interdisciplinary innovations in research and application on campuses and far beyond.

Acknowledgements

The first waves of sustainability students at Florida Tech have been at the center of all academic, campus and community progress. Diverse students have helped drive the courses, enact new green projects, and aid new planning. Morgan Wilson, Lucy Gogin-Muns, and Bryce Beard aided this study. Many other students have contributed to sustainability at Florida Tech. Diverse staff around campus in various offices have assisted including Greg Tsark, Rob Ghiotto, Daniel Sutton, and Holly Chichester of Facilities Operations. Many faculty have also aided program start-up, particularly Gordon Nelson, Rich Aronson, Tom Marcinkowski, Laszlo Baksay, Kastro Hamed, and Hamid Rassoul and Michael Grace of the College of Science Dean’s office. The support of Mark Craddock and Siemens Engineering for the continuing sustainability conferences is acknowledged. The German hosts for this meeting, as the Hungarian hosts for prior meetings, were outstanding and deserve our gratitude for their work.

References


