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Institute for the Study of the Environment, Sustainability and Energy

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Barsema Professor of Social Entrepreneurship, Management
Title: Collaborative Research: Broadening the Fusion of STEM and Business Curricula in Undergraduate Sustainability Education

Award: $2.1 Million, National Science Foundation (NSF-IUSE)

IUSE- Improving Undergraduate STEM Education
SERC- Science Education Resource Center at Carleton College
Research Question:
Can an innovative model of collaborative transdisciplinary sustainability curriculum development – led by STEM and business faculty – better prepare a 21st century workforce to address the wicked problems of sustainability in a global economy?

Vision: Fundamentally transform the way institutions of higher education support transdisciplinary curriculum development.

Assess impact on student learning and faculty perspectives
Problems difficult to formulate and impossible to “solve” because of incomplete, confusing, or contradictory information and involving innumerable stakeholders with conflicting perceptions, needs, and values. (Churchman, 1967)
Meeting the SDGs for a growing global population, in the face of natural resource challenges, all situated within the super-wicked problem of climate change, requires reshaping the way we educate the next generation of decision-makers.

Aim - bring a diverse group of STEM and business faculty to:

1. Develop course modules that introduce complex and transdisciplinary sustainability problems;
2. Create a “common” exercise that introduces the problem and links the disciplines to central theme;
3. Apply discipline-specific content in each course for context while teaching disciplinary concepts.
Transdisciplinary
Interdisciplinary
Multidisciplinary

“[Transdisciplinary thinking] has high aims of reconstituting and rearranging the nature of disciplinary knowledge…through fusion across arbitrary intellectual boundaries”

Stock and Burton (2011)

Diagram credit: UTS Business School, Anthropocene Transition Project
Innovative Curriculum Process

• Backward Design- Start with SLOs

• Develop the curriculum (4 faculty each 3 institutions, ½ STEM/Business)
  1. Address one or more SDGs;
  2. Develop student ability to address transdisciplinary wicked problems;
  3. Improve student understanding of the nature and methods of science and business and how they interact;
  4. Include opportunities for students’ analyses of authentic data and cultural and ethical perspectives; and
  5. Incorporate systems thinking across the curriculum.

• Iterative Process- Tried it, revised it, and then tested it again

• Developed two modules- Next slide

• Cohort 3 and 4
  • Testing of curriculum with other faculty
Two Curriculum Include:

- Curriculum Module (1-2 weeks of a course)
  - Online and in person
  - Slides, handouts, assessment, student guides, data
  - General Education to 400 Level
- Course Specific Exercises
- Instructor Stories
## Courses Where BASICS Modules Have Been Used

<table>
<thead>
<tr>
<th>Accounting Senior Capstone</th>
<th>Environmental Communication</th>
<th>Managerial Negotiations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Marketing</td>
<td>Environmental Geology</td>
<td>Managing a User-Centered Design Team</td>
</tr>
<tr>
<td>Biological Fate of Drugs</td>
<td>Environmental Health</td>
<td>Managing Effective Organizations</td>
</tr>
<tr>
<td>Business Analytics</td>
<td>Environmental Science and Sustainability</td>
<td>Marketing and Operations Fundamentals</td>
</tr>
<tr>
<td>Business Writing</td>
<td>Environmental Studies: Physical Sciences</td>
<td>Marketing Management</td>
</tr>
<tr>
<td>Chemistry of Sustainable Products</td>
<td>Environmental Studies: Water Quality</td>
<td>Mental Health Practice</td>
</tr>
<tr>
<td>Cultural Anthropology</td>
<td>Federal Taxation</td>
<td>Natural Resources &amp; the Environment</td>
</tr>
<tr>
<td>Diversity, Equity and Inclusion in the Marketplace</td>
<td>Financial Reporting and Analysis</td>
<td>Pollution Prevention and Sustainable Production</td>
</tr>
<tr>
<td>Ecology</td>
<td>Freshwater Ecology</td>
<td>Principles of Geology</td>
</tr>
<tr>
<td>Economics and Society</td>
<td>Geomicrobiology</td>
<td>Principles of Microeconomics</td>
</tr>
<tr>
<td>Elements of Environmental Health</td>
<td>Social Entrepreneurship</td>
<td>Race and Racialization at the U.S.-Mexico Border</td>
</tr>
<tr>
<td>Energy Alternatives</td>
<td>Herpetology</td>
<td>Science in Environmental Policy</td>
</tr>
<tr>
<td>Energy and the Environment</td>
<td>Human Biology</td>
<td>Science of Sustainability</td>
</tr>
<tr>
<td>Entrepreneurship and Business Model Designs</td>
<td>Innovation, Social Equity and Entrepreneurship in Media</td>
<td>Social Media Marketing</td>
</tr>
<tr>
<td>Entrepreneurship, Innovation and Sustainability</td>
<td>Intro to Wildlife</td>
<td>Strategic Management</td>
</tr>
<tr>
<td>Environment in the Social Sciences and Humanities</td>
<td>Intro to Environmental Economics</td>
<td>Water Quality</td>
</tr>
<tr>
<td></td>
<td>Managerial Accounting</td>
<td>Wind Energy</td>
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</tbody>
</table>
Impact on Student Learning
Wicked Problem 1: Mississippi Watershed

• Suppose that you were going to address the problem of nitrogen pollution in the Mississippi River watershed. Please indicate how important you think it would be to draw from expertise in each of the following fields in order to solve this problem.

Wicked Problem 2: Plastic Waste

• Suppose that you were going to address the problem of plastic waste and that only a small fraction of plastic is effectively recycled. Please indicate how important you think it would be to draw from expertise in each of the following fields in order to solve this problem.

1 to 5 scale: Not important, Slightly important, Moderately important, Important, Very important
Students completing the Mississippi Watershed module in a course

Mississippi Watershed (n=487-488)

<table>
<thead>
<tr>
<th>Category</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humanities</td>
<td>2.50</td>
<td>3.02</td>
</tr>
<tr>
<td>Business</td>
<td>2.62</td>
<td>3.48</td>
</tr>
<tr>
<td>Social Science</td>
<td>3.55</td>
<td>4.01</td>
</tr>
<tr>
<td>Science</td>
<td>4.06</td>
<td>4.57</td>
</tr>
<tr>
<td>Data</td>
<td>3.79</td>
<td>4.06</td>
</tr>
</tbody>
</table>

Plastic Waste (n=255-257)

<table>
<thead>
<tr>
<th>Category</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humanities</td>
<td>2.40</td>
<td>2.82</td>
</tr>
<tr>
<td>Business</td>
<td>2.73</td>
<td>3.38</td>
</tr>
<tr>
<td>Social Science</td>
<td>3.22</td>
<td>3.63</td>
</tr>
<tr>
<td>Science</td>
<td>3.95</td>
<td>4.14</td>
</tr>
<tr>
<td>Data</td>
<td>3.72</td>
<td>3.95</td>
</tr>
</tbody>
</table>

1 to 5 scale: Not important, Slightly important, Moderately important, Important, Very important

** Highly statistically significant p<.001
"Please rate how much learning you gained from each element you experienced to date in this course"

<table>
<thead>
<tr>
<th>Statement</th>
<th>Cohort 1</th>
<th>Cohort 2</th>
<th>RISC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning that disciplines may approach problems in difference and sometimes conflicting ways (n=525; 510)</td>
<td>4.0</td>
<td>4.0</td>
<td>3.8</td>
</tr>
<tr>
<td>Attempting a complete understanding of a complex problem (n=524; 511)</td>
<td>3.9</td>
<td>3.9</td>
<td>3.65</td>
</tr>
<tr>
<td>Working on a problem that requires integrating ideas from two or more disciplines (n=525; 507)</td>
<td>3.9</td>
<td>3.97</td>
<td>3.5</td>
</tr>
<tr>
<td>Learning to find similarities and differences between disciplines or fields of study (n=525; 508)</td>
<td>3.8</td>
<td>3.8</td>
<td>3.5</td>
</tr>
</tbody>
</table>

1 to 5 scale: None or very small gain, Small gain, Moderate gain, Large gain, Very large gain.

Compared to National Sample from RISC survey 2016 (n=3,506).
Highlights: Faculty Motivations & Barriers

**Motivations**

- Professional development needs
- Improving pedagogy/learning
- Interest in sustainability

**Barriers**

- Increased time and workload
- Fear working outside normal disciplinary boundaries, lack of departmental and institutional recognition (e.g., in P&T)
- Perceive work not considered high (enough) priority by administration
- Experience tensions around disciplinary norms, practices, and language, suitability of the curricula, and confidence teaching it
Implications from Research: Role of Administration

- Help motivate and support faculty with respect to this very complex work
- Key roles in creating and reinforcing policies around teaching innovations
- Launch/sustain cross-disciplinary collaborations; provide resources such as course releases or stipends and teaching awards
- Alleviate concerns for operating outside normal disciplinary and organizational rules by influencing faculty evaluation policies and practices (revisions to teaching evaluations, frameworks and training around P&T review)
- Identify, develop and empower faculty leaders in their teaching
Lessons Learned To-Date

1. Transdisciplinary collaboration can work.
2. The BASICS method for developing a common exercise is challenging, exciting, and relatively “easy.”
3. Convergence on how to frame the wicked problem is difficult and requires top-down support.
4. The iterative, collaborative process can be messy but is both necessary and transformational.
5. Students and faculty benefit from the approach.
Next Steps

NextGen BASICS Leaders
NSF-IUSE
ICT Level 2 ($2M)
July 2024

A. Bentley, NIU & Wittenberg
B. Three additional institutions

Institutional Scaling and Capacity-Building

Growing the Network and Broadening Reputation

NSF-IUSE and Internal and/or External Funding (Private Foundations)

Phase 1: NSF-IUSE ICT Level 2

Phase 2: Monetizing the BASICS model e.g., Aspen Institute Fee-based Services
This material is based upon work supported by the National Science Foundation (NSF) under Grants #1914906 (Bentley University), #1914909 (Northern Illinois University), and #1914913 (Wittenberg University).
A Sustained Cultural and Institutional Transformation in Higher Education that Prepares a 21st Century Workforce to Address the Wicked Problems of Sustainability

<table>
<thead>
<tr>
<th>Ultimate Goal</th>
<th>Long-term Outcomes</th>
<th>Intermediate-term Outcomes</th>
<th>Short-term Outcomes and Activities</th>
<th>Proof of Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achieving Cultural Change at Participating Institutions</td>
<td>Broader Adoption of Transdisciplinary Modules at Participating Institutions</td>
<td>Developing Systems Thinking to Help Address Wicked Problems</td>
<td>Successful Adoption of Modules Beyond LLCs</td>
<td>Sustainability Course Exercise Developed &amp; Assessed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Successful Development of Modules</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Successful Dissemination of Modules</td>
<td></td>
</tr>
<tr>
<td># Faculty teaching modules</td>
<td># Courses with modules</td>
<td># Students taken courses with modules</td>
<td># Transdisciplinary majors/minors</td>
<td></td>
</tr>
<tr>
<td>Website &amp; Online community developed</td>
<td>Best Practices for Transdisciplinary Education Established</td>
<td>Students awareness of &amp; exposure to wicked problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td># Presentations</td>
<td>Development of a website</td>
<td>Assessment of student outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td># Multi-day workshops</td>
<td># Transdisciplinary modules</td>
<td># Administrators engaged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three different institutions</td>
<td>7 PIs</td>
<td># LLCs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Results: Transdisciplinary faculty learning and development of a network of researchers at the intersection of STEM and business
The United States is a consumption-based society whose economic health is dependent on spending and consumption of goods, or products, and services. The impact of our consumption, though, is felt globally. This is most obvious when considered from the perspective of the lifecycle of a product, from extraction of the new resources required for it, to its production and distribution, and, finally, its consumption and disposal. The consequences of each step are both positive (e.g., personal, local, or national wealth) and negative (e.g., habitat destruction, environmental pollution, or human health). Consumption is essential to our economy, but our consumption and ultimate disposal of our consumed products, from food to clothing to electronics, is not sustainable. How will we provide for the consumptive needs of a growing global population if we continue to rely on new resources that are non-renewable or we indiscriminately use or overuse renewable resources? Creating a circular economy is a wicked problem, that is, a complex societal challenge that is impossible to fully solve. Making a circular economy sustainable and making certain it works well for everyone is even more wicked. In this module, students will explore the way complex problems like a circular economy intertwine natural systems with human activities that provide for our physical health and economic well-being.

Goals of the Module

Students are introduced to the multi-faceted nature of wicked problems by exploring the impacts of a linear economy on society and the environment, as compared to a circular economy, which attempts to 'replace the waste of the industrial economy concept with reducing, alternative manufacturing, recycling, and reusing materials in production/distribution and consumption processes.' (Dhoktar et al. 2017, pp. 234-239). The student learning outcomes, however, are much broader and transfers to other sustainability challenges, with focus on how all complex problems disproportionately impact stakeholders, including underrepresented groups and the environment.

After completing the module, students will be able to:

1. Identify ways in which current linear aspects of our economic system shape your own behaviors and norms;
2. Explain a sustainable 'circular economy' from systems perspective;
3. Identify how human and natural systems may affect each other in a circular economy;
4. Evaluate the implications on the environment and social health, and economic equity of a linear and a circular economy.

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Module Overview

Part 1: Waste and the Linear Economy
Part 2: Mapping the Lifecycle of a Product
Part 3: Gallery Tour, Summary Discussion, and Assessment
Student Guides
Instructor Stories by Discipline
Students completing the Circular Economy module in a course

**Mississippi Watershed (n=480-487)**

- Humanities: Pre = 2.64, Post = 4.46
- Business: Pre = 2.92, Post = 3.84
- Social Science: Pre = 3.04, Post = 4.11
- Science: Pre = 3.52, Post = 3.79
- Data: Pre = 3.69, Post = 4.11

**Plastic Waste (n=265-393)**

- Humanities: Pre = 2.52, Post = 3.54
- Business: Pre = 2.85, Post = 3.92
- Social Science: Pre = 2.81, Post = 3.71
- Science: Pre = 3.20, Post = 3.29
- Data: Pre = 3.91, Post = 3.29

1 to 5 scale: Not important, Slightly important, Moderately important, Important, Very important

**Highly statistically significant p<.001**

*Statistically significant p=.01
### Effect Size (Cohen’s D)

Students completing the Mississippi Watershed Module

<table>
<thead>
<tr>
<th>Discipline Category</th>
<th>Mississippi Watershed</th>
<th>Plastic Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humanities</td>
<td>0.523 Moderate</td>
<td>0.440 Moderate</td>
</tr>
<tr>
<td>Business</td>
<td>0.851 Large</td>
<td>0.612 Moderate to Large</td>
</tr>
<tr>
<td>Social Science</td>
<td>0.658 Moderate to Large</td>
<td>0.488 Moderate</td>
</tr>
<tr>
<td>Science</td>
<td>0.108 Small</td>
<td>0.328 Small</td>
</tr>
<tr>
<td>Data</td>
<td>0.269 Small</td>
<td>0.213 Small</td>
</tr>
</tbody>
</table>

Students completing the Circular Economy Module

<table>
<thead>
<tr>
<th>Discipline Category</th>
<th>Mississippi Watershed</th>
<th>Plastic Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humanities</td>
<td>0.305 Small to Moderate</td>
<td>0.367 Small to Moderate</td>
</tr>
<tr>
<td>Business</td>
<td>0.313 Small to Moderate</td>
<td>0.411 Moderate</td>
</tr>
<tr>
<td>Social Science</td>
<td>0.088 Small</td>
<td>0.319 Small to Moderate</td>
</tr>
<tr>
<td>Science</td>
<td>0.044 Small</td>
<td>0.129 Small</td>
</tr>
<tr>
<td>Data</td>
<td>0.269 Small</td>
<td>0.192 Small</td>
</tr>
</tbody>
</table>
Impact on Faculty Change
Imperatives, Challenges, Opportunities

• Transdisciplinarity imperatives: Students’ futures and the social good.

• Limited research documents challenges and gains for faculty engaged in cross-disciplinary collaborations.

• Evaluation of BASICS allows exploration of rare faculty development of transdisciplinary curricula, and its teaching.

• Beyond data for continuous improvement, adding to the research base regarding faculty motivation and affordances and barriers for this work.

Academy of Management
Accelerating Systemic Change Network
American Accounting Association
American Association for the Advancement of Science
American Association of Colleges and Universities
American Economic Association
Geological Society of America
Global Business School Network (Nov 2023)
Earth Educators’ Rendezvous
Lilly Conferences (Jan 2024)
Highlights: Faculty Affordances

- Project leaders were essential alleviators of all tensions, effective facilitators, codevelopers and content/pedagogy experts
- Intensive and in-person work particularly meaningful
- Faculty internalized worth/increased commitment to TD teaching and learning, and topic of sustainability
- Later cohorts have benefitted from continuous project improvement in light of evaluation data
- Faculty seeking additional projects/coordination and funding for their continued work for TD curricula creation and implementation
The Wicked Problem of an Equitable Zero-Waste Circular Economy

BASICS
Business and Science: Integrated Curriculum for Sustainability

serc.carleton.edu/basics
BASICS Student Learning Outcomes

**Identify** ways in which currently linear aspects of our economic system shape your own behaviors and norms.

**Explain** a sustainable “circular economy" from a systems perspective.

**Identify** how human and natural systems may affect each other in a circular economy.

**Evaluate** the implications on the environment and on social, health and economic equity of a linear and a circular economy.