Synergistic Learning & Inquiry through Characterizing the Environment for Sustainability (SLICES): Improving Understanding of Real World Systems through Observation & Reflection

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Abstract – This paper presents initial results of research on modes of learning combining undergraduate research with work-based learning or internships to create a program for synergistic learning and inquiry. The research combines these two types of experiential learning into an inquiry-based internship experience that builds on existing strong institutional programs at Virginia Tech, aligns well with the goals of all participants, and taps a larger, more diverse body of students than is typically able to be reached by undergraduate research programs alone. The objectives of the research are to fill gaps in the existing knowledge base about the impacts of such programs on diverse student populations, the efficacy of hybrid experiential learning methods for sustainability pedagogy, and the role of such programs in setting the stage for positive change toward sustainability in industry. The paper presents findings from a 2007 pilot along with plans for subsequent investigation and program dissemination.

Keywords: Internship, work-based learning, experiential learning, sustainability

TEACHING SUSTAINABILITY: GOALS AND OPPORTUNITIES

While there is general support for the idea of incorporating sustainability as part of higher education curricula, agreement is lacking as to the best way to do so [Jones, 25; Wals, 54], and a variety of pedagogical challenges exist that are unique to the concept [Lourdel, 38]. To be effective, the literature suggests that pedagogical approaches for teaching sustainability-related concepts should incorporate inquiry, experience, and reflection as an integral part of instruction [Moore, 41; Riley, 46; Shriberg, 50], and can benefit from being situated within the context in which the concepts will be used [Anderson, 3; Graham, 18; Jucker, 26] rather than as isolated curricular elements [Haigh, 20]. Jucker [26] also advocates for self-determination in learning about sustainability, where students are empowered to take responsibility for their own learning experiences. Jucker [26] identifies four attributes of effective integration of sustainability concepts as part of teaching and learning, including (1) Full integration of sustainability concepts into the curriculum; (2) Student-centered activities and assessments that reward critical thinking and reflective learning; (3) Trans-disciplinary teaching and learning; and (4) Teaching that emphasizes that sustainability is an ongoing process without hard and fast answers.

Scholars such as Resnick [45] and Alvarez and Rogers [2] take integration a step further and argue that moving study from the classroom into the field of study has considerable additional value in that students are able to directly observe and engage in the implementation challenges faced by practitioners and ground their theoretical understanding of sustainability in reality. Local embedded understandings, experiences, and knowledge become a part of student experience and provide considerable insight to explain what is observed. This transition from an “investigative” to an “interpretive” approach to sustainability better reflects the context-dependent nature of sustainability [Wals, 54]. Moreover, direct engagement goes beyond demonstration to involve students in influencing the outcomes about which learning is undertaken [in Graham, 18].

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The pedagogy proposed in this research is oriented around various modes of experiential learning, defined by Cantor [9, p. 1] as "learning activities that involve the learner directly in the phenomena being studied." Typical activities classified as experiential learning include interning, field work, service learning, in-class simulations, and others, although some researchers include any learning that involves doing something, including taking notes in a lecture or participating in a discussion. The benefits of experiential and inquiry-based learning with regard to sustainability are well-acknowledged [Almgren, 1; Ellis, 14; Jucker, 26; Dawe, 12], and such learning is also recognized as being supportive of the development of tacit knowledge, providing context in which to understand the relationship between practice and theory, and developing professional skills that can enhance employability [Ellis, 14] and increase retention [Nagda, 42]. This research focuses on two specific types of experiential learning common in engineering undergraduate education: inquiry-based learning in the form of undergraduate research, and work-based or work-integrated learning in the form of internships.

Undergraduate Research Outcomes and Critiques

With the recommendations of the Boyer Commission's landmark report on Reinventing Undergraduate Education [7], the path forward to effective integration of teaching and research in engineering was established, and faculty were encouraged to "…treat the sites of their research as seminar rooms" as a way to create a synergy between student learning and discovery of new knowledge in which faculty are traditionally engaged. Over ten years later, there are numerous examples of such programs [Guterman, 19; Bauer, 5], although the percentage of undergraduates participating in research remains comparatively small and is typically limited to the strongest students or students in specifically targeted populations [Hancock, 21; Russell, 47]. Undergraduate research is most common in fields involving laboratory science and is least common in non-laboratory social sciences and humanities, with engineering fields somewhere in between.

Among the benefits of collaboration between researchers and students on real projects is a sense of trust established between the parties that increases the engagement of students in the process [Maguire, 39], although to be truly effective, scientists must derive benefits in their role as scientists rather than philanthropists or mentors [Means, 40]. A variety of assessment approaches have been undertaken to measure the impacts of undergraduate research programs and determine the value added these programs provide [Lopatto, 37]; methods range from surveys, interviews, and ethnographic studies of student and faculty, to quasi-experimental evaluation of effects on post-research career and academic plans, to faculty review of student work (ibid.). Typical research experiences involve students working individually or in small groups with different faculty on specific research topics of interest, which poses an assessment challenge for comprehensive program evaluation. Skills that are typically enhanced by undergraduate research experiences include ability to understand concepts; use relevant information and literature; identify research questions, formulate hypotheses, and design an experiment or theoretical test; observe, collect, statistically analyze, and interpret data; relate results to the "bigger picture" and communicate results orally and in written form; and think independently [Kinkead, 31; Sabatini, 48; Landrum, 35; Lopatto, 37].

Internship Outcomes and Critiques

Internship programs are also an integral part of many engineering and construction programs throughout the U.S. [Tener, 53; Wiggins, 55], and partnerships between industry and universities are increasing in importance for a variety of reasons [Hansen, 22]. The link between the classroom and the real world is essential to the growth of the student. Internships give students exposure to more than the academic side of an industry and enable them to apply classroom material more effectively. The benefits to students of exposure to engineering practice as part of a curriculum are well documented [Schuurman, 49]. Internships also engage industry and faculty and encourage the development of mentoring relationships. Overall, internships help to develop a well-prepared graduate who is ready to accept the roles required to become successful in his or her chosen career.

The ASCE BOK 2 emphasizes the importance of obtaining relevant work experience as part of its Guidance for Students [ASCE, 4], and highlights the critical nature of finding the right first job as a matriculating engineer. Lifelong and experiential learning and reflection are also critical components of recommended practice by ASCE. The increased interest in work-based or work-integrated learning since the late 1990's has been driven by employer concerns that students are not prepared for the demands of the modern workplace. Critics of this trend observe that such "market-driven" educational approaches tend to reinforce the status quo rather than innovation among employed students [Hansen, 22]. Cotgrave & Alkhaddar [11] observe that a high level of literacy and self-efficacy is essential if students are to change the construction industry after graduation rather than conform to existing industry practices.

When successful, the benefits of experiential work-integrated learning and university-industry partnerships extend to students, industry, and faculty alike [Table 1, adapted from Clements, 15; Hansen, 22; Lamancusa, 34]. Clements also notes that successful work-integrated learning programs should include flexible hours for non-work activities such as assessment, which can be facilitated by e-learning and therefore not interfere with work requirements [10].

Table 1: Benefits of work-integrated learning and university-industry partnerships

Benefits to Students	Benefits to Industry	Benefits to Faculty/Academia
• Gaining professional work experience • Developing skills for applying knowledge to practical problems • Developing ability to work effectively in a professional environment • Enhancing employability • Stability to focus on study and "learn as you earn"	• Receiving assistance on real situations rather than contrived projects • Ability to view and nurture potential employees • Ability to place students with minimal disruption to normal work environment • Not having to provide particular learning tasks • Flexible placement options	• Provision of a well-rounded, sustainable learning environment • Opportunity to build collaborative relationships with industry partners • Ability to maintain relevance to industry practices and benchmark academic programs to industry best practice in an agile way • Opportunity to contribute to the community • Practice-oriented learning experiences better engage students

Together with undergraduate research programs, work-integrated learning in the context of industry internships offer two alternatives to traditional pedagogy in achieving effective integration of sustainability as part of engineering education. The potential benefits of integrating the two into a hybrid experiential learning experience are described next.

Precedents: Combined Research and Internship Programs

There is some precedent for formally combining field data collection, reflection, and analysis with the internship or industry visit experience. For instance, Domask [13] describes an optional research component of the required internship program in International Environment and Development that involves students in formulating a research question, undertaking interviews with relevant stakeholders, and analyzing and summarizing results. Students participate in approximately six class sessions where they are guided through the research process by supervising faculty. Benefits of this program, according to Domask, are greater grasp of complex sustainability topics by students, the ability to see multiple sides of a given issue through interacting with multiple stakeholders, and greater opportunity for work experience that may lead to future employment (ibid.). In this program, each student defines his or her own topic and research question and pursues data necessary to answer it. The program also includes written and oral reflection about the internship experiences shared with peers and instructors, which further contributes to the learning process [Domask, 13, based on Kolb, 32, and Fenwick, 16].

A second precedent for integrating these concepts is the internationally acclaimed Global Learning and Observation to Benefit the Environment (GLOBE) program, where K-12 students use rigorous research protocols as part of science education to collect data locally that is then used by for research by the scientific community [Becker, 6; Butler, 8; Kennedy, 30]. In existence since 1993/1994, this program incorporates rigorous training for K—12 educators and standardized equipment and protocols to help ensure data accuracy while generating widely distributed spatial-temporal data sets [Butler, 8]. Various appropriate protocols are available for multiple grade levels and subject areas to provide multiple opportunities for integration of the program within standardized education [Means, 40]. Scientific data collected by the GLOBE program ranges from land cover data to weather observations and soil properties and has been used to "ground truth" data collected by scientists using other methods and develop and validate predictive models [Becker, 6; Butler, 8; Kennedy, 30]. Essential to data quality are effective pre-collection learning activities for students and training on relevant protocols and equipment for teachers [Becker, 6; Wormstead, 56]. The web-based platform for data collection facilitates collection and storage of data and provides the ability to incorporate a variety of analysis and data visualization tools for research and educational purposes. Competitively selected research teams develop GLOBE protocols and review data generated by students prior to using that data in their research [Butler, 8]. Formal assessment of the program has found a positive impact on students' ability to use scientific data in decision making and their scientifically informed awareness of the environment [Butler, 8], which are key sustainability skills identified as being relevant for sustainability education.

Another precedent, the Australian-based Farming the Future program [Alvarez, 2], involves students and instructors in field trips with considerable interactions with stakeholders to understand and interpret sustainability within the socio-cultural and ecological context in which those stakeholders exist. Student skills identified by Alvarez and Rogers as resulting from this model of study include the ability to listen carefully, assess, analyze and question their own assumptions; be open to the possibility that useful or important information is not always the preserve of experts or paid professionals; see a community in all of its complexity and not expect one position or response to be held by all; and understand how people can commit to change for reasons other than the ones policy makers or students feel they should. These are precisely the skills that are required for lateral thinking to grasp sustainability concepts in their context of application. Still other industry inquiry programs occur on a much smaller scale as modules within individual courses, where students work in small teams to analyze situations and visit industry partners to conduct interviews for additional information. However, programs such as these are focused on active learning for students more than broader data collection efforts where such data could be incorporated in faculty research.

Unifying themes in successful student-scientist partnerships identified by Harnik & Ross [23] include generation of scientific data of useful quality, educational evaluation to document learning outcomes, and meaningful and well-balanced partnerships where the interests of all are addressed. Benefits to the research community include the ability to develop datasets that would be otherwise unobtainable due to the magnitude of effort required for their collection. Harnik and Ross also note that data resulting from these types of partnerships can sometimes increase data quality when the use of non-specialists to collect it shields it from researcher bias, although lack of confidence in student observations can also be a barrier to use of the data by researchers (ibid.). Key to the motivation of student participation is a belief that they are contributing to a scientific research project and that their contributions are being used and validated by researchers [Harnik, 23; Jarrett, 24; Means, 40].

SYNERGISTIC LEARNING & INQUIRY APPLIED AT VIRGINIA TECH

Experiential learning in the form of undergraduate research and internships results in multiple benefits for involved stakeholders [Clements, 10]. The aim of the program described in this paper is to combine these two types of experiential learning into a sustainability learning and inquiry experience that builds on existing strong institutional programs at Virginia Tech, aligns well with the goals of all participants, and taps a larger, more diverse body of students than is typically able to be reached by undergraduate research programs alone. If successful, this program will fill gaps in the existing knowledge base about the impacts of such programs on diverse student populations, the efficacy of hybrid experiential learning methods for sustainability pedagogy, and the role of such programs in setting the stage for positive change toward sustainability in industry. The point of departure for the research is based on preliminary findings from a pilot test of the integrated learning/inquiry model for partnerships between students, researchers, and industry conducted as part of the Building Construction (BC) internship program at Virginia Tech in 2007.

The SL**ICES 2007 Pilot Program**

The internship program is an integral part of the BC Program at Virginia Tech. Students may intern with the same employer over multiple summers, or choose to experience different employer environments. The sponsoring employer provides a salary based on internship and other work experience in exchange for an opportunity for the student to gain industry experience and exposure while contributing to company operations. Internship work experiences in the construction domain are progressively offered in three primary areas: field operations, office operations, and project management [Fiori, 17]. The majority of undergraduate BC students at Virginia Tech choose to participate in summer internships, with many taking a for-credit option earning three credit hours that has been offered since 2003. In 2008, 100% of BC graduates had participated in at least one summer internship experience during their degree program, and 68% enrolled in the internship for credit option for at least one summer. Historically, the requirements for this course included writing a statement of goals, keeping a daily journal, writing a paper summarizing the experience, completing a presentation about the internship, and returning an employer evaluation. This nine-week internship experience provided students with opportunities to problem solve, think critically, and utilize knowledge learned in the classroom.

During the summer of 2007, the internship for credit program undertook an experiment to increase student responsibilities during their internship program and enhance student learning about sustainability in the construction industry. Throughout the summer, students were tasked with five assignments that required them to research sustainability practices within their companies. This new approach combined the experiential learning of an internship with a structured undergraduate research experience for internship participants. The pilot program, denoted Synergistic Learning & Inquiry through Characterizing the Environment for Sustainability (SLICES), concluded with 39 participants completing all requirements for the internship during Summer 2007.

Objectives for the pilot program were to: (1) Improve interpersonal skills and leadership; (2) Develop students' abilities to complete independent research; (3) Increase the advancement of meta-cognitive skills; and (4) Provide for peer-to-peer interactions across companies during the internship period. In order to meet these objectives, a course structure was developed to guide students through the process of planning, executing, evaluating, and reflecting on data collection exercises within their companies and synthesizing their findings resulting from these exercises.

Five protocols were developed for the pilot program, each focusing upon different aspects of the adoption of innovative, sustainable construction practices. The protocols were distributed to the students via a Blackboard Site at one to two week increments throughout the summer. The students completed the protocols and submitted the data through an online survey for review and analysis by the SLICES team. Table 2 provides an overview of the protocols [available in Pearce, 43] included in this module.

Table 2: Sustainability Protocols and Description

Protocols	Description
Your Company, Your Job, and You	Submit basic data about your background, your internship position, and the company for whom you'll be working
Corporate and Leadership Innovativeness Factors	Characterize your company and its employees in terms of factors that affect its innovativeness
Baseline Sustainability Best Practices	Inventory what your company currently does from a sustainability best practice standpoint both in the corporate office and on the job site
Understanding Adoption of Sustainability Best Practices	Choose three sustainability best practices your company uses and learn more about their experiences
Recommending New Best Practices	Develop a set of recommendations for your company to improve sustainability, and interview company personnel to evaluate their feasibility and appeal

During the 9-week period students were required to give feedback about the protocols, discuss their experiences in completing the protocols, and learn from each other regarding the challenges they were experiencing while completing the assignments. This was accomplished through a discussion board on the Blackboard site. The faculty monitored the discussion board throughout the summer and responded to student questions and suggestions for improvement.

In addition to basic understanding of sustainability and information literacy skills, the underlying skills being cultivated during the internship experience are part of a set of competencies known as *managerial resourcefulness* [Kanungo,27, 28, 29]. In the pilot study, students were pre- and post-tested using the managerial resourcefulness inventory developed by Kanungo & Menon [28] as a measure of learning throughout the summer. Qualitative evaluation of learning was also undertaken during a final debrief session, and students were also encouraged to complete a written questionnaire to provide feedback on the experience. The results of this evaluation provided valuable feedback and lessons learned [Fiori, 17] that can be used to improve the learning outcomes, research protocols, and course logistics.

Specific SLICES Improvement Opportunities Based on Pilot Tests and Literature Review

The 2007 pilot program revealed a number of specific improvement opportunities that should be addressed, including a need for the following [Pearce, 43; Fiori, 17]:

- Increased pre-internship training for students on etiquette, research methods involving human subjects, basic communication skills, and managing priorities during data collection, including what to do when desired data is unavailable.
- Introduction to web-based technologies used in the course, including online surveys for data input.
- Increased contact with participating companies prior to the internship regarding internship requirements and potential benefits of providing support and cooperation to interns attempting to complete the protocols.

- Mechanisms to assess data accuracy during the internship process so that problems can be corrected before the conclusion of the internship.
- Improvements to the existing protocols to remove redundancy and provide structured classifications for responses instead of free responses for many questions to facilitate subsequent data processing and analysis.
- Development of a protocol to provide guidance for faculty on how to develop new protocols that takes into account lessons learned from experience with undergraduate researchers.

There was also an opportunity to expand the reach of the internship program to include students from each of the three construction-related degree programs at Virginia Tech, including Building Construction (BC), Construction Engineering & Management (CEM), and Civil & Environmental Engineering (CEE). Additionally, the program can also benefit from rigorous assessment of its impact and methodologies to enhance the academic rigor and acceptability of the program by other scholars. Lastly, there are multiple significant methodological challenges identified in the literature associated with assessing learning outcomes resulting from integrated research-education programs such as SLICES. Some relevant challenges identified in the literature that are being addressed in the current research include:

- Self-rating of learning of research skills, e.g., research design, data collection, literature review, etc. may not accurately reflect learning objectives for programs designed to reach all types of undergraduates [Bauer, 5].
- Obtaining adequate sample sizes for assessment of outcomes and establishing control groups may be difficult given the pedagogical goals of integrated research-education programs whose aim is to provide access to participation for all interested and eligible students [Bauer, 5].
- Data accuracy must be verified and protocols carefully designed to ensure that student-collected data can be used for rigorous research purposes [Becker, 6; Harnik, 23; Penuel, 44; Wormstead, 56].
- A lack of rigorous research design, failure to account for how learning assessment data were collected/analyzed and how issues of validity, reliability, and ethics were managed, and self-selection bias and lack of control groups may raise issues of academic credibility with regard to program evaluation and assessment [Fein, 15; Stewart, 52].

One of the greatest challenges faced by the research team was a change in department leadership during the Fall of 2007. The new administration changed the internship procedures and students were no longer able to receive credit for their summer internship experiences. The researchers have successful convinced the leadership to re-instate the option and the Summer 2010 offering will be the first opportunity to implement the new processes.

Objectives of the Current Research

To address the needs identified in the previous section, the objectives of the current research are three fold:

1) Revise and enhance the SLICES Program based on identified needs, including the development of a boot camp experience for students prior to their internships, and test the enhanced program in practice
2) Create and implement mechanisms for rigorously assessing the learning impacts and impacts to other stakeholders resulting from the program
3) Establish an infrastructure for success that will support the diffusion of the SLICES Program and enhance its broader impacts.

The primary revision to the SLICES Program is the implementation of the boot camp to prepare students for their experiences during the summer. The boot camp is a course that meets seven times during the semester. Lectures and assignments are designed to engage students in activities similar to those they will be expected to complete as part of the SLICES Program. Students are also able to review the protocols prior to the start of their internship and an entire class session is devoted to the review of the protocols. These steps are critical to ensure student buy-in to the overall process and to improve the level, reliability and accuracy of the data collected. Table 3 is a summary of the topics and assignments covered in the boot camp.

The underlying hypothesis for the research is that students participating in the SLICES internship program will demonstrate greater levels of cognitive and affective sustainability knowledge, managerial resourcefulness, and information literacy than students who participated in non-SLICES internship experiences or did not participate in internships at all. The assessment design employed in this research employs a three-pronged approach to test this hypothesis while addressing the methodological challenges identified earlier: (1) a longitudinal alumni study; (2) assessment of currently enrolled students; and (3) assessment of impacts on companies.

Table 3 : Boot Camp Lectures and Assignments

Week	Classroom Topic	Homework Assignment
1	Introductory Class Purpose and Goals of class Class Schedule Internship Requirements Student Introductions	Research 2 companies attending the career fair and develop 10 questions you would use to follow up with the company representative to gain additional information unavailable on their web site or in promotional materials
2	Present and explain how you completed research Interviewing tips Awareness of Self/ Finding Strengths	Identify/list personal strengths and weaknesses Contact Internship Company and ask follow up questions developed.
3	Discussion of Strengths and Weaknesses Discussion of Career Fair Interviews Resourcefulness and Investigation Analyzing Information Provided	Investigate sustainable practices and processes used in Bishop-Favrao Hall through personal interview, observation and research
4	Discuss findings and processes/what worked and what did not work Setting up for a successful interview- Evaluating the environment through prior research	Interview 2 students who have done internships to evaluate their experience/ analyze information
5	How can interviewing other students help you with your internship Best Practices of interns	Synthesize best practice information into something that is presentable to future interns
6	Sustainability Protocol Handouts and Review	Review/read and develop questions Post to site
7	Protocol Question Discussion	

Expected Outcomes of the Investigation

The expected outcomes of this research include a revised and tested SLICES model, including improved protocols, a pilot tested intern “boot camp” curriculum, and data validation plan; formal documentation of the assessment results of the SLICES Program, along with validated assessment tools that can be used on an ongoing basis to evaluate impacts of this program at Virginia Tech and other institutions; and a set of program infrastructure resources to facilitate the adoption of the SLICES model by other institutions and increase the broader impact of the research. Ultimately, the proposed research will contribute to a better understanding of the impacts of experiential learning about sustainability concepts through inquiry-based internships. Students participating in the program will benefit from learning about sustainability in the construction industry while enhancing their skills for inquiry, reflection, managerial resourcefulness, and information literacy. Industry participants will benefit from access to benchmark information about the state of sustainability in the construction industry, the opportunity to learn more about sustainability from their interns, and the opportunity to have recommendations posed to them by students on how to increase their corporate sustainability. Participating faculty will benefit from interactions with industry, more satisfying faculty-student interactions supported by peer-to-peer learning, and access to industry data to support their research for a relatively low expenditure of faculty labor. Successful outcomes in this research will lead to future opportunities to expand the SLICES model to other disciplines at Virginia Tech and to programs at other universities. There may also be opportunities to expand the model to community colleges and K-12 institutions as well.

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