On the Development of an Undergraduate Course on Sustainability Research Methods

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ON THE DEVELOPMENT OF AN UNDERGRADUATE RESEARCH METHODS COURSE FOR STUDENTS ENROLLED IN SUSTAINABILITY PROGRAMS

Abstract

An interdisciplinary team at the University of Arkansas is developing an undergraduate course that will be devoted to teaching methods and techniques for conducting research in the field of sustainability. This domain is complex due to its interdisciplinary nature within engineering and between engineering and other STEM and/or non-STEM disciplines. Furthermore, research methods span from strictly quantitative to more qualitative extremes adding to the complexity. Sustainability curricula are developing a focus on applied research and solution oriented projects. Students need, however, to comprehend the systems perspective of a problem, create a vision for change, and ultimately provide a solution to address such a challenge. Academic rigor and proper student preparation are primary motives for developing these abilities to initiate transformational strategies towards sustainability issues. From our academic experience and literature review, it is apparent an opportunity exists to tailor current methods of inquiry to sustainability, or emerge with new ones that are more fitting. The ability to conduct research is learned through initiation with continued practice and builds from a foundation of understanding the different approaches that are available. This paper shares the process engaged in this course design and development aimed at preparing undergraduate students, including engineers, with the knowledge to successfully carry out sustainability research.

Introduction

Stemming from the popularization of the term sustainability in the Brundtland Report in 1987[1], momentum for the incorporation of the discipline has taken shape in the form of instruction in higher education.[2, 3] Formalizing the discipline has required buy-in from academic institutions and an acknowledgement of its veracity. The goal of supporting sustainability findings rests upon the ability to replicate the procedure and provide generalizations to larger disciplinary landscapes. Defined curricula for teaching this accepted research process in sustainability is currently fragmented. Central to the challenge is the accomplishment of replicable and generalizable results on a consistent basis to a multi-faceted problem. This has been done in the arenas of multi, inter, and trans- disciplinary research, but not in this emerging comprehensive discipline. In other words, when scientific research is conducted in any field, it is important that the same results be achieved through repeated procedure and be generalized. There are criticisms that the sustainability field lacks reliability and validity in this context of traditional research.[4] When a discovery is made in science, it is evaluated on the procedure used to reach the final results, which ultimately leads to a discussion of research methods. The acceptance of sustainability as a prominent discipline is not uniform. This effort presents an opportunity to build on the progress from the formative years of the discipline to develop the proper procedures for conducting sustainability research at an undergraduate level.

Initially, traditional disciplinary research method instruction was applied to the sustainability arena. This field calls, however, for a multidisciplinary perspective that promotes approaches across disciplinary boundaries. However, the first attempts at integrating sustainability education were constrained by the artifacts of these research procedures that produce knowledge in other

disciplines. Inclusion into the emerging discipline requires a conscious effort to adapt the research instruction to the holistic, diverse, and multi-faceted nature of sustainability. This approach to building genuine notions for the field is becoming common in related programs and aims to remove the shackles of past scientific paradigms.[5, 6] Innovation is a key piece to the plan of action to facilitate sustainability research that strives to gain respect and supporting resources. This new thinking and creativity is agreed upon to come from capacity building and training in collaboration management.[7, 8, 9] These applied skills focus on building a model for the citizen that promotes sustainability. This goal is important, however from the standpoint of research methods, the rigor of the methodologies for training a researcher must also be addressed. Therefore, the student training fostered by the methods course developed at the University of Arkansas will concentrate on this gap in building the model researcher in sustainability.

Model Researcher

The model researcher has the goal of advancing knowledge. Basic and fundamental research with a purpose combines the elements of building knowledge and defining best practices for practical use. Currently, a similar model is lacking a comprehensive implementation in the sustainability field. [10] Acknowledging that this is important, it is necessary to complement the capacity-building process and draw from examples of traditional research methods to provide the theoretical grounding for the field of sustainability.

Starting with the underpinnings of scientific revolutions, researchers represent the definitive thirst from the academic and research community to strive for a refined understanding of the world around us. The great thinkers such as Aristotle, Plato, Ptolemy, Franklin, Newton, Lyell, and Lavoisier all provided foundational thought to many of our core disciplines.[11] These original findings were not meant to be the end, but rather the starting point. From this point forward, scientists from across the disciplines have endeavored to conduct research that answers old questions and presents new paradigms to challenge entrenched modes of thinking.[12] Research methods literature describes the creative potential in pursuing research and the importance of following outlined guidance.[13] It is this ever-adaptive approach to spawning knowledge that we call research methods. *The important thing to remember in this quest is that change is the constant*. Just as sustainability is coming up with new ways of economic valuation, social community building, and environmental awareness, the field of research methods is a complementary driver for adaptive competence.

Knowledge is forever being created and refined. This is an important consideration to keep in mind moving forward to the cross-disciplinary approaches that test the limits of this tentative by adding in more variables and perspectives in the sustainability setting. Change at the theoretical level is more difficult to encourage, however it is the necessary step for teaching sustainability research and training future influential researchers. The final commentary in *The Age of Science: What We Learned in the 20th Century* calls the future of science to embrace knowledge-seeking in the realm of sustainable development.[14] Development is framed in the social evolution that is influenced by the multitude of scientific discoveries in the past century. What all of the numerous scientific discoveries have in common is that they were spurred from research. Therefore, this paper on research methods follows this framework to provide the guidance for future discoveries, starting with an overview of the foundational traditional research methods.

Traditional Research Methods

Digressing from the mutual effect of theory on practice and vice-versa in the cycle of research, knowledge gain emanates as the result of a leap from thought to action-validation. Indeed, the process of research moves from the purely philosophical realm and proceeds with outlined guidance in the form of a methodology. Research methods pursue realism in their characterization of knowledge and draw on theoretical structures to proceed in this direction.[15] Paradigms of science supply navigation to researchers, which is why it is important to train students in the accepted methods of conducting research. The traditional research methods are a starting point for conversation of what is appropriate for the emerging discipline of sustainability.

To provide a framework for the purpose of research methods it is useful to draw from the foundational work of Pasteur[16] (Figure 1). His quadrant points to the differences in research that can clearly be distinguished between basic and applied research.[17] The y-axis represents the first distinction of defining the direct outcomes of the research. Basic research is associated with the advancement of knowledge primarily and developing theories for why things are the way they are. The y-axis depicts the relevance to the advancement of knowledge with basic research associated with a greater degree of relevance because of its theoretical implications. Whereas, the x-axis represents the second distinction of the ability of research findings to be applied in the practical setting. The classic examples represented in the quadrants below are Niels Bohr for the pure basic research who was responsible for determining atomic structure and defining quantum mechanics, Thomas Edison for the pure applied research who owns the most individual patents and created a number of useful inventions, and lastly Louis Pasteur for use-inspired basic research who contributed to numerous microbiological application findings (e.g. pasteurization) and also foundational theories (e.g. germ theory of disease). The cross section between building knowledge and practical application is an ideal research outcome and relates directly to sustainability.

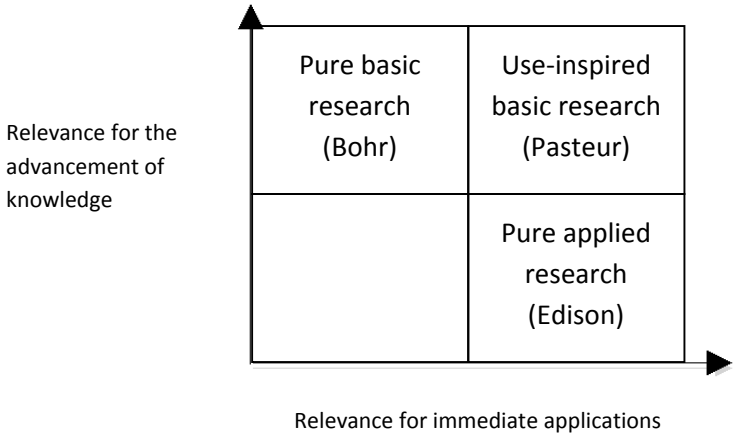

Figure 1. Pasteur's Quadrant outlines the classification for scientific research methods.[18]

To examine the landscape of traditional research methods that are relevant to the emerging discipline of sustainability, we will define a sample set of traditional research methods

responding to the criteria of basic or applied research, and quantitative or qualitative research. For each of the research methods enlisted below, a brief description of the process is provided to show their respective fit into the quadrants. In the following section, these methods will then be critically examined in the context of sustainability.

To start with, the canonical definitions for the research categories and approaches are the following. Basic research produces theories that become the foundation for further study of phenomena.[19]Applied research involves investigation of a current problem or practical issue that is being faced in the professional or academic setting. Applied research differs from basic research because the goal of indicating foundational knowledge is not pursued and the solution sought after is applicable to the specific situation.[20] Quantitative research is defined by methods that place explicit numerical values on results and provide calculations. Numbers allow for concrete interpretation and a visible level of measurement that is driven by deduction.[21] Lastly, qualitative research includes methods that investigate information encompassing emotions, social trends, cultural values, etc… that cannot be alone defined by quantification.[22] These distinctions will help organize the following set of research methods that represent the traditional approaches to conducting research.

Beginning with an example of basic research that uses qualitative approaches, **theoretical research** is focused on using *reason* and *logic* to examine research questions. Developing theories that define how and why relationships exist allows more mission-oriented research methods to determine the validity of findings.[23] In Pasteur's quadrant, theoretical research falls into the basic research and can be used for pure basic research and use-inspired *basic research*. Theoretical research pushes researchers to think and ask questions about why things are the way they are.

Experimental research methods are associated with providing a basis for *applied research*. Through experiments, researchers can determine causality between two or more variables. The process involves investigators designing experiments where different components are altered in order to pinpoint the source of change or influence in a system. Experimental research branches from the process of arguing from observation alone and using defined and replicable experiences to substantiate claims.[24] Experimental research commonly uses quantitative measurements and is useful for comparing findings from the past. Experiments are vital to supporting findings to substantiate the veracity of research results.

The next example of traditional research methods is **simulation research**. This approach expands upon the experimental realm by extrapolating the simulation to a real world situation. The goal is to develop a model that simplifies reality so investigators can determine what variables are significant in a given situation.[25, 26] Simulation research uses quantitative indicators to define results and is primarily used in the applied setting.

Interpretative research closely aligns with the *basic research* quadrant of Pasteur's. This research is designed to examine alternative viewpoints and theories to assess validity of different perspectives fostered by current social processes.[27] This curiosity-driven research method asks the researcher to allow the variables to emerge during investigation and to be critical of the underpinnings of different perspectives, while doing his or her best to remain unbiased about the

outcomes and value-free. Therefore, the focus is on building social understanding of what shapes knowledge.[28] Interpretative researchers look at history and current events to provide useful knowledge. Interpretative research is primarily qualitative and relies on literal descriptions rather than numbers.

In connection to interpretation's focus on descriptive findings, **survey research** is another example of qualitative research, but that is instead used in the applied research setting and also uses quantitative indicators. This research method relies upon interviews, questionnaires, and focus groups to gather information. Both numbers and qualitative assessments can be produced from this process of research. Researchers rely on available sources of data. Survey research aims to gather a broad-based assessment of what exists, in what amount, and in what context in regards to the research topic.[29] *Survey research is capable of being multi-faceted in the basic/applied and quantitative/qualitative dimensions.*

The last example of traditional research methods is **action research**. This form of research is gaining popularity in the applied setting and aims to contribute to knowledge building from examples of ideas put into practice. Researchers actively participate in action research with the goal of engaging in the process of change. This research method gives investigators a close relationship to the research area and allows them to build a direct understanding of the research area. With action research, participation is the main driver, not only of the individual, but also with other collaborators in the sample environment.[30] Researchers examine information from what they propose to do, then get feedback from the practice, and then refine their ideas. This form of traditional research is actually what is getting implemented into most sustainability teaching settings.[31]

The presented typologies provide a general overview of traditional research methods that exist in science and that could be applicable to the realm of sustainability. Before moving to the emerging discipline, however, we will examine the landscape of research that crosses the disciplines.

Multi, Inter, and Trans- Disciplinary (MIT) Research Methods

Multi, inter, and trans-disciplinary (MIT) research methods calls on the experience of the scientific community in quest of advancing objective knowledge.[32] Because these research methods cross the disciplinary boundaries and combine traditional research method typologies, there is a call to define the shared processes that do exist in these modulations. The root of the motivation for these research methods is the belief that a topic or issue would benefit from multiple perspectives, which is a similar characteristic of sustainability research. Whether it be to double-check accuracy of findings or to find new solutions and answers, these research methods open up new doors in knowledge.[33]

The structure sets no limit to the number of perspectives that can be integrated into the research method. This flexible structure for incorporating involvement has resulted in a dynamic landscape of applications. Typically, use of these research methods occurs in the academic and the practical setting. These two environments dictate similar structures of implementation, and

for the purposes of this paper we will focus on the academic arena. The following typologies reflect efforts in the scientific community to overlook the boundaries of disciplines. Whereas disciplinary research describes investigations in a specific academic discipline, **multidisciplinary research** describes an additive or sequential process of combining concepts or methods from different disciplines.[34] The precursor of "multi" suggests a simple mixing without any additional integrative efforts of planning and coordination. This represented the start of crossing disciplines and focused on adding rather than integrating methods. The conscious step of concerted inclusion occurs in the onset of interdisciplinary research.

Interdisciplinary research expands upon multidisciplinary research because of the inclusion of integration. There is an intentional and necessary coordination of the research that goes beyond simply mixing methods. Drawing from the general education movements arising post World War I and from the cultural revolution of the 1960s, interdisciplinarity arose to show a unity of knowledge and focuses on crossing disciplinary boundaries.[35] Interdisciplinary research has shared the support of "big science" initiatives such as nuclear science where scientists came together for a common goal and created new knowledge and innovations together.[36]Collaboration was focused in the scientific arena, whereas the transdisciplinary research pushes these bounds further.

The beginning of transdisciplinary research has no specific starting point, however the term itself was created in the 1970s.[37] In the Berkshire Encyclopedia of Sustainability, **transdisciplinary research** is defined as "a particular mode of research in which researchers, experts, policy makers, business leaders, and citizens collaborate in developing solution options to complex societal problems such as a lack of sustainability".[38] Building off of the integration of interdisciplinarity, there are explicit actions taken to collaborate. The difference is found in pursuing the final step from action-oriented research to developing solutions. The findings are translated to action utilizing the new discoveries of knowledge.

Systems Thinking Approach

All of these latter forms of applying more than one research method to a particular problem have experienced success in implementation and reflect how the traditional research methods can be broadened beyond their initial scopes. The common theme is the use of systems thinking to the process of research. In systems thinking, cause and effect is seen as a dynamic rather than a linear progression that spans from different avenues and decision vantage points. Research methods are outlined so researchers can understand the process of how the knowledge was created and provide support for why the findings are verifiable. By looking at the whole system and a number of disciplines, however, researchers begin to see how their efforts must shift to also include a model for combining research methods.

The following table identifies the key differences that exist between the traditional process of research examined earlier and the identifying characteristics of systems science.

This table below shows how open the systems approach is to broadening research outcomes and how directly involved the researcher is in the gathering of data, even influencing the research itself. This framework is used as the springboard for a significant discussion bringing together

the elements of the research puzzle into the discipline of sustainability. The nature of cross-cutting disciplinary research is problem-driven and solution oriented. The motivation for new knowledge is not unique from traditional research methods, but the collaborative impetus does provide a defining characteristic. In every alternative form of disciplinary research, there is an essence of collaboration. Promoting dynamic integration embraces the challenge to bounded specializations that ignore the need for systems thinking in the sustainability field.[39] The systems that exist naturally and in our built environments do not adhere to a strict set of guidelines as individual disciplines outline.[40]

Table 1. Key Distinctions between Classical and Systemic Orientations

Perspective of Classical Science		**Perspective of Systems Science**
Analysis, Reductionsim Entity	**Mode of Enquiry**	Synthesis, Expansionism, Emergence Process
Cause-Effect, Determinism	**Reasoning**	Non-deterministic, Purpose, Meaning
Objectivity, Observer detachment	**Rule**	Observer Involvement and Influence
Prediction Identity	**Goal**	Understanding Activity
Goal-driven, Negative feedback, Adjust for error	**Control**	Goal-driven Positive feedback, change of goals

Source: "A Taste of Systemics," by B. Banathy, 1997, International Society for the Systems Sciences. <http//www.isss.org/taste.html>

The major hurdle met is the paradigm of education advocating the distinction of disciplines from the early years and eventual departmental structures of higher education.[41] The formation of sustainability science accounts for the need of adopting the broader scope of understanding theoretical dispositions because of the systemic issues that are prominent in the field.[42] The mix of knowledge needed to provide effective guidance requires a suite of research methods.[43] It is our goal in this course development project to create an experience for undergraduate students that introduces them to the practice of research and informs them about collaboration.

The notion of interdisciplinary methods refers to the practice of triangulation, which involves using multiple data-gathering techniques to investigate the same phenomenon. This practice allows for confirmation, but it also produces avenues to result in alternative perspectives. Combining qualitative methods with quantitative methods often reveals new opportunities for measurements or different explanations not revealed in a singular approach. The Repko text used in many interdisciplinary research courses encourages students to consider the multiple disciplines to determine what is most relevant to the topic of research, then decide which methods are directly applicable from those disciplines.[44] This approach differs from Wiek's promotion of genuine approaches to sustainability, since these methods hold the input of their respective disciplines and are retained in data collection.

The eclectic character of the educational Cartesian disciplines constrains thinking in sustainability because of the focus on structures and bounded theories that are entrenched. A sustainable research method intends to break away and ask researchers to be ingenious in their

approach to problem-solving. The step that is added to Repko's guidance for research is an adaptation of the research methods. Wiek emphasizes the building of core competencies connected to collaboration that stresses the release of paradigmatic constraints and new theories for creating knowledge in sustainability. The main message is that sustainability deserves its own ingenuity in adapting approaches rather than simply combining what is already available in the structured disciplines. This paper offers an introduction to the discussion of how to complement the core competencies and practical skills with research proficiencies. A research methods course for students in sustainability programs should cover a wide array of the traditional and MIT methods in order to offer a strong foundation in conducting both basic and applied research. Then, with the impetus of sustainability, students can discover how to strive for Pastuer's idea of use-inspired basic research that has both practical application and theoretical implications.

The following syllabus excerpt represents our efforts to integrate our investigation of the above mentioned research methods and how we envision the class forming to foster the development of researcher in sustainability.

Bringing it to the Classroom

The new course will be included in the sustainability minor, and forthcoming sustainability Bachelors of Science degrees at the University of Arkansas. This course will examine the theories, methods and techniques of research applied to the sustainability field in order to expand the knowledge and understanding regarding the practices of this new discipline. In sustainability research, the endeavor is to also consider the relationship and relevance of this domain to other disciplines and professions. Hence, select methodologies will be covered to enable the students' pursuit of interdisciplinary research. Among them, various quantitative and qualitative research methodologies will be studied. Typically, each of the research methodologies (i.e. lifecycles) will proceed from idea generation, development of a problem statement, development of solid hypotheses and/or research questions, effective literature searches, design of appropriate research methodologies (including obtaining Institutional Review Board approval if necessary), collection of data/information, analysis of data/information, assessment of work, and dissemination within the broad domains of sustainability. Research carried out in sustainability is complex due to its interdisciplinary nature, and exposing students to the various types of research such as basic vs. applied, experimental vs. survey, model-based, etc. is necessary.

Specific course learning outcomes will further be developed, and are expected to include the following:

Learning objectives:

- Add depth to understanding the sustainability paradigm and theories.
- Recognize the purposes and implications of sustainability research.
- Understand and properly select from the variety of research methods, those appropriate to the sustainability problem.
- Learn to conduct interdisciplinary research in sustainability.

Preparation of sustainability research:

- Structure and write a research proposal (e.g. Honors College grant application, NSF graduate fellowship application or thesis proposal); *Deliverable: Research proposal*
- Structure and write an undergraduate thesis (i.e., abstract, introduction and previous work, statement of problem, objectives, methods, data and data representation, discussion, references, along with methods for appropriate attribution (citation), data visualization (charts, graphs, tables, etc.); *Deliverable: Thesis outline*
- Write a research abstract for a research conference, conference paper, or journal paper; *Deliverable: Abstract suitable for submission*
- Prepare a research presentation (e.g. poster or oral) for a professional conference or symposium; *Deliverable: Poster and Powerpoint presentation*

An excerpt of the course syllabus for the first four weeks of class is shown below:

Week 1

- Introduction to traditional research methods
  Assignment: Find a past example of research using one of the traditional research methods and be prepared to share with the class.

Week 2

- Review of traditional research methods
- Introduction to multi, inter, and trans-disciplinary research methods
  Assignment: Find a current research article that uses interdisciplinary research methods and describe the different methods they use. Compare with the article you brought in last week and provide a critique of how the current research incorporates and does not incorporate the traditional research method.

Week 3

- Introduction of developing research proposals
- Begin to brainstorm in class with fellow students project interests and which research methods would be appropriate
  Assignment: Choose two research methods that could apply to your area of interest and develop a synopsis of a proposed research project

Week 4

- Each student will present to class their synopsis and peers will provide feedback
- Introduction of collaboration and techniques for working with multidisciplinary perspectives
  Assignment: In small groups of 2-3 students, create a networking map that shows the links to different disciplines that apply to your respective research projects and think about which professors or departments will be important partners in the research.

Conclusion

The research methods course will incorporate teachings of the traditional research methods and the cross-cutting disciplinary research that apply to the sustainability field. The goal is to teach students the process of conducting research from a basic and purpose focused perspective. For reference, the original six broad student learning objectives for the University of Arkansas sustainability programs are as follows.

1. Articulate commonly accepted definitions of sustainability and discuss various nuances among those definitions.
2. Have an understanding of the interdisciplinary nature of sustainability issues, particularly as they pertain to the thematic areas of knowledge addressed by the minor (sustainability of natural systems, managed systems, built systems, and human social systems).
3. Be conversant regarding acquisition and analysis of data pertinent to sustainability issues.
4. Communicate orally and in writing organized thoughts defining sustainability issues.
5. Identify appropriate potential strategies to address sustainability issues using data and provide results of rudimentary analyses of data using novel metrics or statistics.
6. Make recommendations, based on data analysis and interpretation, to advance sustainability of individuals or institutions.

The research methods course addresses 3-6 of the sustainability program learning objectives. The process of conducting research and gaining experience in creating a sustainability research project is outside the scope of the originally developed introductory courses in the sustainability program. Therefore, a sustainability course devoted to research methods will give the students the necessary knowledge to complete their capstone projects and increase the quality of work.

Future plans are to design a full curriculum to include such a course during the 2013-2014 academic year. We will evaluate the success of the projects and the students' comprehension of traditional research methods and how they can be adapted to the field of sustainability. To reiterate, the goal of this curricular development was to build a model for the researcher in sustainability to complement the efforts in other course to build the capacities of collaboration and visioning needed in future careers. We look forward to integrating this course into the growing embracement of sustainability at the University of Arkansas.

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