Tools for Problem- and Project-based Learning in Sustainability Science Education:

A Case Study of Two Undergraduate Classes

by

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A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree of
Master of Arts

Approved April 2013 by the
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May 2013
ABSTRACT

Teamwork and project management (TPM) tools are important components of sustainability science curricula designed using problem- and project-base learning (PPBL). Tools are additional materials, beyond lectures, readings, and assignments, that structure and facilitate students’ learning; they can enhance student teams’ ability to complete projects and achieve learning outcomes and, if instructors can find appropriate existing tools, can reduce time needed for class design and preparation.

This research uses a case study approach to evaluate the effectiveness of five TPM tools in two Arizona State University (ASU) sustainability classes: an introductory (100-level) and a capstone (400-level) class. Data was collected from student evaluations and instructor observations in both classes during Spring 2013 and qualitatively analyzed to identify patterns in tool use and effectiveness. Results suggest how instructors might improve tool effectiveness in other sustainability classes.

Work plans and meeting agendas were the most effective TPM tools in the 100-level class, while work plans and codes of collaboration were most effective at the 400 level. Common factors in tool effectiveness include active use and integration of tools into class activities. Suggestions for improving tool effectiveness at both levels include introducing tools earlier in the course, incorporating tools into activities, and helping students link a tool’s value to sustainability problem-solving competence. Polling students on prior use and incorporating tool use into project assignments may increase 100 level tool effectiveness; and at the 400 level, improvements may be achieved by introducing tools earlier and coaching students to select, find, and develop relevant tools.
ACKNOWLEDGEMENTS

I would like to thank:

Dr. Redman, Dr. Pijawka, and Dr. Mo for their direction,

Vicki Fulkerson for editing and moral support,

Katja Brundiers for her mentorship throughout my Master’s program,

Brian, Kate, and Mary for keeping me sane, and

all of the wonderful teachers who have inspired me to care about education.
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INTRODUCTION

Teamwork and project management (TPM) tools are important components of sustainability science curricula designed using problem- and project-based learning (PPBL) methods. Tools are additional materials, beyond lectures, readings, and assignments, that instructors often provide to students in order to structure and facilitate their learning; they can enhance the student team’s ability to complete projects (Oakley, 2002; Oakley, et al., 2004; Baninjarian & Abdullah, 2009) and, if instructors are able to locate appropriate existing tools, can reduce time typically needed for class design and preparation (Hung, 2011).

Selection and implementation of appropriate tools for PPBL classes in sustainability will be aided by an understanding of how TPM tools can structure and facilitate learning differently in classes of different levels taking into account that project complexity and student competence increase progressively throughout a program (Brundiers, Wiek, and Redman, 2010; Pijawka, et al., 2013). Review of literature on sustainability science education, problem- and project-based learning (PPBL), challenges to implementing PPBL in sustainability education, and tools available to help instructors do so reveals little literature on what kinds of tools support project completion in different levels of an undergraduate sustainability programs or what tools support acquisition of key competencies in sustainability in PPBL settings.

The objective of my research is to help sustainability instructors create better PPBL learning environments by providing evidence-based insight into TPM tools that help students develop teamwork and project management skills, which are fundamental
to interpersonal and strategic competence in sustainability at many levels. My research uses a case study approach to evaluate the effectiveness of TPM tools used in two different ASU sustainability classes: an introductory (100-level) and a capstone (400-level) class, containing 15 and 11 students respectively. Both classes engage a PPBL approach in which students work in teams to explore sustainability problems and study or develop solution options through a semester-long project. Both classes provide students with a similar set of TPM tools including: 1) meeting agenda and notes template, 2) code of collaboration guidelines, 3) work plan template, 4) teamwork guidebook, and 5) methods selection worksheet. My research was guided by the following questions:

- Which TPM tools are most effective the 100-level sustainability class?
- Which TPM tools are most effective in the 400-level sustainability class?
- What factors contributed to effectiveness of TPM tools in these classes?
- How can instructors improve the effectiveness of TPM tools in other classes?

To answer these questions, data was collected from student evaluations and instructor observations conducted in both classes throughout Spring 2013. Data was analyzed using sets of sub-questions and descriptive codes to identify patterns in tool use and effectiveness.

Research found that work plans and meeting agendas were the most effective TPM tools in the 100-level class, while work plans and code of collaboration were most effective in the 400-level class. Common factors in effectiveness include active use of the tool by more than one student and integration of tools into class activities. Introducing tools earlier in the course, incorporating tools into activities, and helping students link
tools’ value to sustainability problem solving competence might improve effectiveness of tools at both levels. Polling students on prior use, incorporating tools into assignments, and helping students connect value of tools to sustainability problem solving competence may increase tool effectiveness at the 100 level. Introducing tools earlier in a sustainability program and coaching students to select, find, and develop relevant tools may increase effectiveness of TPM tools at the 400 level. Furthermore, this research points to a need for progressive curriculum models in sustainability education (Brundiers, Wiek, and Redman, 2010; Pijawka, et al. 2013) that would help instructors design classes, which includes selecting effective TPM tools, that are appropriate for students’ progressive competence at each successive level of a program.
LITERATURE REVIEW

This review will consider literature relevant to selection, design, and effectiveness of teamwork and project management (TPM) tools in sustainability education; define key terminology; identify conceptual gaps with practical implications for sustainability instructors; and help readers understand why and how an evaluative case study will assist sustainability instructors to improve the effectiveness of the TPM tools they select and implement. First, it provides a context for considering the effectiveness of TPM tools by describing the typical steps involved in designing and preparing a PPBL class. Then, it presents the goals of sustainability science education (SSE) and the key competencies necessary for sustainability problem solving, explores why PPBL has been considered an ideal approach to teaching the knowledge, skills, and attitudes relevant to key competencies in sustainability, considers the challenges to implementing this teaching and learning approach in sustainability, and explores TPM tools available.

Backward Design

To provide a meaningful context for discussion of TPM tools in PPBL, it is important to review two common educational design methods: Backward Design (Wiggins & McTighe, 2005) and Constructive Alignment (Biggs, 2001), hereafter referred to as Backward Design since this approach incorporates and builds on Constructive Alignment. Backward Design provides instructors with preparatory steps to help ensure that the various elements of course design – goals, learning objectives, pedagogy/approach, teaching and learning activities, and evaluation techniques – align and will consequently produce desired learning outcomes (Biggs, 2001 and Wiggins &
McTighe, 2005). Backward Design steps are as follows: 1) Define the desired learning outcomes and objectives; 2) Design teaching and learning activities; and 3) Select appropriate evaluation techniques. Instructors choose PPBL tools based on their appropriateness for the class’s learning objectives (Step 1) and for the teaching and learning activities designed to achieve these objectives (Step 2). Tool selection and use is a sub-component of the second step, teaching and learning activities.

Figure 1 provides a visual of the typical Backward Design process. It shows how TPM tools fit with other course design elements and identifies specific elements of the two sustainability classes featured in my case study. The three basic educational design steps are shown across the top, in sequence from left to right, and major implementation elements are shown directly beneath. Components of the two sustainability classes are aligned below each corresponding implementation element. The red arrows indicate the flow of both design and implementation. It is important to note that evaluation occurs iteratively throughout the PPBL class, providing information to help instructors and students adjust teaching and learning throughout a class.
Figure 1. TPM Tools in Sustainability Classes. This figure illustrates the steps in Backward Design, components of an aligned class, and where TPM tools fit.

Sustainability Science Education

Teamwork and project management, and the tools used to support them, are fundamental to sustainability science education (SSE) because they help students learn to work collaboratively to problem solve. SSE strives to train scientists capable of working in a problem-based, solution-oriented space that spans traditional disciplinary boundaries and requires collaboration with other disciplines, professionals, and stakeholders in order to develop sustainability solution options (Kates, et al., 2001; van der Leeuw, et al., 2012). Wiek, Withycombe, and Redman (2011) recently identified five important competencies specific to SSE that college-level students need to develop (in addition to basic competencies such as critical thinking) in order to engage in sustainability problem solving. These are systems thinking, anticipatory, normative, strategic, and interpersonal competence. Table 1 defines each of the SSE key competencies.
Table 1  

**Definitions of Five Key Competencies in Sustainability**  
(Wiek, et al., 2011)

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<tr>
<th>Competence</th>
<th>Definition</th>
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<tr>
<td>Systems Thinking</td>
<td>The ability to analyze complex systems across different domains and scales, considering features of sustainability problems such as cascading effects, inertia, feedback loops (p. 207).</td>
</tr>
<tr>
<td>Anticipatory</td>
<td>The ability to analyze, evaluate, and craft pictures of the future related to sustainability problems and solution options (p. 208).</td>
</tr>
<tr>
<td>Normative</td>
<td>The ability to map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets (p. 209).</td>
</tr>
<tr>
<td>Strategic</td>
<td>The ability to design and implement interventions, transitions, and transformative governance strategies towards sustainability (p. 210).</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>The ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving (p. 211).</td>
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Sustainability competence demands that students apply overlapping competencies, in collective problem-solving environments to get things done (Barth, et al., 2007 and Wiek, et al, 2011). As such, key sustainability competencies are not merely knowledge sets that students can learn through traditional lecture/assignment approaches and recite for evaluation through traditional means. Furthermore, it is not reasonable to expect that students who are instructed in a traditional and perhaps disengaged manner will be able to apply the key competencies on their own in real-world contexts.

Students do not necessarily need to develop all five sustainability competencies to equal degrees; collaborative research enables those with different knowledge and skills to build teams with collective competence. When students have a general awareness of the competencies, the manner in which they interrelate, and the resulting achievements possible, they can make educated decisions regarding the skills and abilities they want or need personally and to complement those of their collaborators (Wiek, et al., 2011).  

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Interpersonal competence underpins development and application of the other four competencies (Wiek, at al., 2011). For example teamwork and project management are vital skills for “getting things done” in sustainability projects. Consequently, learning objectives related to teamwork and project management are fundamental to all levels of SSE in an undergraduate program.

**Problem- and Project-based Learning**

PPBL is an experiential approach to teaching and learning increasingly used by sustainability instructors to help students develop contextualized knowledge of problems and solutions as well as knowledge, skill, attitudes important for sustainability problem-solving (Stauffacher, Walter, Lang, Wiek, & Scholz, 2006; Domask, 2007; Row, 2007; Brundiers, Wiek, and Redman, 2010; Segalàs, Ferrer-Balas, & Mulder, 2010; Brundiers & Wiek, 2011; Frisk & Larson, 2011; Dobson & Tompkins, 2012). PPBL draws on constructivist theories of learning, which suggest that students learn best when they have to “construct” knowledge for themselves through personal experience rather than absorb pre-constructed knowledge through classroom lectures (Kolb & Kolb, 2005; Frisk & Larson, 2011; Roessingh & Chambers, 2011). Constructivist theories also recognize knowledge as more than information about something, seeing it rather as a combination of knowledge, skills, and attitudes that enables students to understand or do something (Frisk & Larson, 2011).

PPBL is a hybrid form of two unique but complementary approaches to teaching and learning: problem-based learning (PBL) and project-based learning (PJBL). PJBL was developed during the progressive education movement of the early 20th century by
William Kilpatrick. In PJBL, projects are use as teaching and learning activities to engage students and drive learning (Roessingh & Chambers, 2011). PBL was developed in the health sciences in the 1970s and ’80s in an effort to replace exhaustive, information-focused lectures and clinics with more interactive training that prepared students to work in applied contexts with a rapidly evolving medical knowledge base (Savery, 2006). In PBL, students or teams of students are given a “messy”, “ill-structured problem” – one without a clear answer – and the objective of developing a solution, which then structures and drives learning thorough the duration of the activity.

PBL, PJBL, and PPBL have been implemented in classes, programs, schools, and entire universities, as supplements to or comprehensive replacements of traditional approaches, in fields as diverse as health sciences, urban planning, engineering, sustainability, and humanities at K-12, undergraduate, and graduate levels (Shepherd & Cosgriff, 1998; Hmello-Silver, 2004; Savery, 2006; MacVaugh, & Norton, 2012; Dobson & Tomkinson, 2012, Edutopia, 2013). Individual instructors seeking new ways to teach material often implement these approaches informally. Alternatively, an approach may be formalized into program- or school-wide models and applied systematically throughout an organization; examples include Maastricht University’s 7-Jump Method (Moust, Van Berkel, and Schmidt, 2005) and The Aalborg Model (Aalborg University, n.d).

As previously mentioned, PPBL combines PBL and PJBL, and so brings the best of both worlds together. The basic goals of PPBL include helping students become self-motivated and self-directed learners with an extensive and flexible knowledge base, transferable problem-solving skills, and collaborative competence (Hemlo-Silver, 2004).
Teachers take on the role of facilitator; they foster students’ self-motivation and helping them take increasing responsibility for their own learning process. Other common components include student collaboration; reflection as key to the learning process; and a focus on complex, open-ended questions that offer opportunities to produce work that is of value to the real world (Savery, 2006). Formative assessment and evaluation occurs continually throughout classes, feeding information back to students, to help them achieve learning objectives, and instructors, to help them improve teaching activities, Barron, 1998). Techniques such as self- and peer-evaluation (Ash & Clayton, 2009), reflective journals (Gulwaldi, 2009), rubrics (McKeown, 2011), and student portfolios are used to assess and evaluate multi-dimensional learning that might not be observable through traditional techniques like final examination. Effectiveness of PPBL, PBL, and PJBL has been debated. Some studies conclude these approaches are effective, and some conclude they are not. Belland, French and Ertmer (2009) note that the validity of many assessment studies of PBL is undermined by undefined constructs and lack of evidence presented by authors on the reliability and dependability of their data. Further more, as Hung (2011) writes, “In pondering why PBL research persistently produced inconsistent or even conflicting results, it is noted that previous research efforts…appeared to debate the two ends of the instructional process—the theoretical conception and students’ learning outcomes—without discussing the processes, that is the implementation (p. 530).” This more nuanced critique observe that “effectiveness” of PPBL depends on a variety of factors including what instructors are trying to teach, how they implement teaching and learning activities, and how they assess and evaluate learning outcomes how well
instructors and students adhere to the evidence-based principles and guidelines of their selected approach (Moust, et al., 2005; Hung, 2011).

**PPBL and Sustainability Science Education**

PPBL is particularly appropriate for sustainability science education (Bereiter & Scardamalia, 2003; Brunetti, Petrell, & Sawada, 2003; Stauffacher et al., 2006; Brundiers, et al., 2010; Segalàs et al., 2010; Dobson & Tompkins, 2012). The goals, components, and learning outcomes of each align quite closely (Brundiers, et al., 2010). Dedicated to producing student change-agents, PPBL asks students to identify and delve into very messy, complex and contested problems (Wiek, 2010) and to develop solutions. The nature of these problems – life threatening, complex, urgent, place-based, normative, contested, long-term – requires collaboration amongst peers as well as across traditional disciplinary boundaries in research and practice (Kates, et al, 2001; Wiek, 2010; Lang, et al., 2012). Movement away from topical specialization towards transferable key competencies builds students’ ability to move between different problems and different problem contexts (Barth, et al., 2007; Wiek, et al., 2011). A PPBL approach is appropriate for SSE since it involves understanding problems, which is emphasized in problem-based learning, and developing solutions through collaboration with peers from other disciplines as well as stakeholders, which is emphasized in project-based learning (Barron, 1998; Brundiers, Trippel, Redman, and Wiek, in prep). However, there are a number of challenges to implementing PPBL in SSE, and these will be discussed below.
Challenges to implementing PPBL. Research suggests that PPBL must be implemented according to evidence-based principles and guidelines in order to have its promised effect (Moust, et al., 2005; Hung, 2011). Typical challenges to implementing PPBL in any field include instructors’ unfamiliarity and lack of expertise with PPBL as well as the amount of time required for planning, implementation, and assistance to students who must take on more responsibility for the projects and self-directed learning than they are used to; challenges for students include unfamiliarity with PPBL, lack of capacity to participate in collaborative, project-based learning, and lack of motivation to take responsibility for learning (Ertmer & Simons, 2005; Hung, 2011). Additionally, the SSE setting presents a unique set of challenges. Instructors must design projects that target the famously “wicked” sustainability problems and produce viable solution options by creating multiple types of knowledge (descriptive-analytical, normative, and strategic knowledge), yet are not too complicated or demanding for students to accomplish in a semester, year, or other time-period designated by the academic schedule.

One of the biggest obstacles for implementing PBL, PJBL, and PPBL in SSE classes relates to misperceptions stemming from a lack of understanding, lack of familiarity with implementing these approaches in different settings, and experience with poorly implemented classes. A commonly heard misperception is that PPBL only works in fields like medicine and engineering, where problems are not as complex as in sustainability, and solutions are not required to be systemic and long-term. This perception is laden with several questionable assumptions.
One assumption made by those who compare the use of PPBL in SSE unfavorably to its use in other fields is that the solutions targeted in those other fields are indeed fundamentally less complex than those required in sustainability; that solutions to sustainability problems must be more complicated than solutions in other fields in order to be applicable to complex problems. In fact, sustainability draws many of its theories and methods from fields like planning, environmental science, and ecology; fields that continue studying sustainability problems and solutions often through PPBL and similar teaching and learning approaches (Pijwaka, et al., 2013). For example the renewable energy solution developed by Mark Henderson’s team of engineering students for the Navajo Nation took shape through a PPBL class where problem and solution analysis involved consideration of long-term social and ecological impacts (Henderson, personal communication, February 6, 2013). Furthermore, simplicity/manageability is valuable to any solution in order to avoid compounding the problem (Perrow, 1984).

Another assumption made in comparing PPBL in SSE to other fields is that the complexity of sustainability problems requires a knowledge-first approach that makes development of viable solution options impossible in classroom learning settings. Solutions-oriented research is already a component of many sustainability programs, however. Frameworks like Sustainability Solutions Agenda (Sarewitz, et al., 2012) and Transformational Sustainability Research (Lang, et al, 2012) are already applied in sustainability classrooms. In one class, students ultimately connected residents of a Phoenix neighborhood with city services to implement a native species Tree-and-Shade program.
A third assumption is that PBL, PJBL, and PPBL hybrids are the same approach. Because these approaches are based on similar theories of learning, have similar components, and are often used interchangeably, they are often thought to be the same thing. As described above, they are not. Hybrid approaches of PPBL are recommended for the field of sustainability because they bring knowledge of how to design learning experience around complex, ill-structured problems without single solutions (like sustainability problems) together with knowledge of how to design learning experience around short, team-based, product/solution-oriented projects.

Yet another assumption is that PPBL doesn’t teach content, but teaches skills and processes instead. On the one hand, sustainability instructors might need to expand their conceptions of sustainability content from descriptive-analytical knowledge about things to include skills and attitudes, as all are necessary for students to develop solution (Barth, et al. 2007; Wiek, Withycombe, and Redman, 2011; Frisk and Larson, 2011). On the other hand, instructors must learn to design PPBL projects so that they require students to encounter the content that instructors would otherwise relay directly in traditional learning environments (Henderson, personal communication, February 6, 2013). This can be achieved by carefully designing problem framings and project objectives so that students must engage in relevant content areas in order to complete their projects (Ertmer & Simons, 2005). It may also be achieved by teaching fundamentals for PPBL success, like teamwork and project management, early on in an undergraduate program so that students don’t have to spend all of their time and energy developing these basic skills and dealing with consequences of poor teamwork and project management later.
Tools for Instructors

Creating or compiling tools to structure and facilitate learning is an important part of designing teaching and learning activities and can be done strategically to overcome challenges to implementing PPBL. Teamwork and project management tools, for example, can help sustainability instructors meet many generic challenges by decreasing the amount of time and expertise instructors need to design and implement a PPBL class. They may also help students take responsibility for project work and self-directed learning by aiding with organization, communication, collective team memory and reflexivity, time management, and strategic planning. As such, they may structure learning activities in ways that facilitate achievement of PPBL learning outcomes. TPM tools can also help sustainability instructors deal with challenges to implementing PPBL that are unique to sustainability. For example, tools like work plans and methods selection worksheets help students work backwards from sustainability project objectives to design a project that allocates time for descriptive-analytical, normative, and strategic phases so that students don’t get stuck in the first descriptive analytical trap (Sarewitz, 2012) and never complete a solution option through their project.

Instructors can avoid assigning an “impossible” task that might lead to frustration and apathy among students by first verifying that adequate resources, including tools, exist for students to find and or use during the PPBL process (Ertmer & Simons, 2005). Identifying peer-reviewed or evidence-based tools such as presentations, case studies, guidelines, and templates may help instructors overcome some of the challenges to implementing PPBL laid out in the previous section because instructors don’t need to
have the time or expertise to create the tools themselves (Brundiers, Trippel, and Wiek, in prep). Tools for instructors teaching PBL, PJBL, and PPBL at the K-14 levels are available through websites from organizations like Edutopia, The Buck Institute, University of California Santa Cruz, and McMaster’s University.

Edutopia, from The George Lucas Educational Foundation, strives to improve K-12 education by “documenting, disseminating, and advocating innovative, replicable, and evidence-based strategies that prepare students to thrive in their future education, careers, and adult lives” (Edutopia, 2013, Mission para. 1). Many of these strategies center around project-based learning, and the website includes examples of activities, readings, and tools that help students learn about PJBL and engage in this potentially new teaching and learning environment. Activities recommended include watching case study videos of projects completed by other students, discussing how to ask useful questions in PJBL, defining what constitutes a good project, and agreeing on how projects and performance should be evaluated. Resources for instructors include an extensive bibliography of peer-reviewed studies on PJBL (Vega, 2012a), a presentation that explains what PJBL is and how it can improve teaching and learning, and a project template that instructors can use to think through the logistics of planning, facilitating, and evaluating a PJBL project (Edutopia, 2012).

Other tools and resources can be found dispersed throughout Edutopia’s case studies and best practices for successful PJBL. One article features Manor New Technology High School in Manor, Texas, a school that has designed a complete PJBL-based curriculum; it provides a list of best practices and links to tools like a peer review
protocol and group contract templates used by instructors at this school. The Peer review protocol facilitates honest, two-way feedback between students and instructors throughout the course by structuring feedback around three statements: “I like…”, “I wonder…”, and “Next steps….” The Group Contracts Template documents expectations of students’ performance and provides structure for identifying and addressing problems in individual performance if it arises (Nobori, 2012). Another article on the website demonstrates that these best practices and tools have been used with good results – the school has a 98% graduation rate and 100% college acceptance rate for graduating seniors, 50% of whom are first-generation college students (Vega, 2012b).

The Buck Institute for Education is another organization that strives to improve education “by creating and disseminating products, practices and knowledge for effective Project Based Learning” (Buck Institute for Education, 2013a, para 1). Their website features an entire page of tools for implementing PJBL at K-14 levels. These tools include project calendars and work plans, rubrics for creating rubrics, a project overview template, a collaboration rubric, and a team contract (Buck Institute for Education, 2013b). Some of these tools are designated for specific grade-levels, while others are generic. All are created by the Buck Institute and are free and easily downloaded for printing and distribution.

University of California Santa Cruz, Sustainable Engineering and Ecological Design shares a diverse array of teaching materials on its website, including course syllabi, class and lab lesson plans, and tools for group projects. Although the program is not explicitly framed as PJBL, many of the tools are used in collaborative,
interdisciplinary, problem-based, and solution-oriented environments with a focus on sustainability. Lab topics include defining sustainability problems and exploring social components of life cycle analysis. Tools include descriptions of purposes of different types of data collection methods, an explanation of differ approaches to project evaluation, templates for group work plans and project briefs, and guidelines for presentations (SEED, 2011).

McMaster’s University’s website also compiles a variety of teaching and learning resources. These include concept mapping activities, which are often used to help students get started with PBL projects, and techniques for assessing students prior knowledge, which is important in all forms of PBL, PJBL, and PPBL so that instructors can provide the appropriate amount of scaffolding to student projects (McMaster University, n.d.). Although The School of Medicine at McMaster’s was one of the first to implement problem-based learning throughout its curriculum in the late 1960s, few of the resources on this site are specifically indicated for use in PBL, PJBL, and PPBL.

There is no shortage of tools and other resources available for instructors who are looking for materials to help them implement PPBL. There is little information available, however, on which tools are most useful at different educational levels (K-graduate) and how these tools are best introduced to students to enable desired learning outcomes. Are work plan templates useful for teams at ninth grade and graduate levels, for example? Should instructors spend more time introducing this tool at the undergraduate 100 level, perhaps because freshmen have never used it before? Or would students at the 400 level benefit from more discussion about the how to use a work plan because they have already
developed foundational interpersonal and strategic competencies that enable them to use a work plan more effectively in their projects?

**Synthesis and Opportunities**

Instructors increasingly use PPBL in sustainability classes, since this approach lends itself well to teaching knowledge, skills, and attitudes through real-world experience. The impetus of research on PPBL is shifting from debating its effectiveness to exploring how to implement it well so that it leads to its promised outcomes (Hung, 2011). Factors that influence PPBL effectiveness in terms of student task performance and student learning outcomes include instructor roles, group size and structure, student engagement and self-directedness, problem structuring, project objectives (Moust, et al., 2005), and available tools (Baninjarian & Abdullah, 2009). Consequently, many fields are undertaking “how-to” research and experimentation: how to design PPBL classes and curricula; how to incorporate PPBL components into existing classes; how to switch from the traditional instructor role to being a coach; how to help students used to traditional methods of instruction thrive in PPBL settings that require more engagement, responsibility, reflection, and reflexivity; and how to assess and evaluate learning in PPBL settings. One component of PPBL implementation in sustainability that could use more attention concerns tools instructors can provide to students to help structure and facilitate learning.

A plethora of tools are available for instructors who want to incorporate PPBL into their classes. Tools include templates, examples, and guidelines to supplement lectures, readings, and syllabi that help students achieve course learning objectives.
Currently, most easily accessible tools come from education organizations like the Buck Institute and The George Lucas Educational Foundation, although some can be found on the websites of schools and universities. Most are intended for K-12 classrooms rather than college and graduate classes. Few of these tools were developed in or intended for sustainability classes, making it unclear if and/or how they should be adapted for sustainability contexts to support students’ acquisition of key competencies in sustainability. Furthermore, little discussion addresses which tools are appropriate for different levels in an undergraduate sustainability curriculum and how instructors should adjust the tools and their use at different levels.

My research will use a case study approach to evaluate five teamwork and project management tools provided to support students in a 100- and a 400-level sustainability class and explore how instructors can provide students with these tools in the most effective way. Teamwork and project management are the focus of this study because they are integral to interpersonal and strategic competencies, which are essential for enabling students to work in teams and across disciplines and domains to get things done (Wiek, Withycombe, and Redman, 2011). In my experience as a sustainability graduate student and teaching assistant, teamwork and project management are both valuable learning outcomes in their own right, as well as essential prerequisites for achieving content-specific learning outcomes through PPBL (Hung, 2011) and completing project work with real-world value to community research partners (Brundiers & Wiek, 2011). Conversely, deficiencies in these and other components of interpersonal and strategic competence undermine other desired outcomes. As such they make a good starting place
when thinking about how to teach key competencies in sustainability at different levels of a program.

The five TPM tools that I will evaluate are as follows: a meeting agenda and notes template, a code of collaboration guidelines, and a work plan template (all variations of tools commonly used in PPBL), as well as a teamwork guidebook and a worksheet for choosing a research method (the latter were developed by staff and students of the School of Sustainability and walk students through procedures and practices common in teamwork and project management like identifying team roles and picking a method that will produce information appropriate for a team’s research question). All five tools are currently used in undergraduate classes at the Arizona State University – School of Sustainability. By evaluating these TPM tools and exploring how instructors can make them more effective in various levels of a sustainability program, my research will produce evidence-based insight to help sustainability instructors implement PPBL to teach key competencies in sustainability throughout an undergraduate curriculum.
APPRAOCH AND METHODS

My research uses a case study approach featuring two different sustainability classes offered at Arizona State University (ASU) during spring semester 2013 (January-May). Case study approach is rooted in the social sciences (LeCompte & Schensul, 1999; Creswell, 2009) and commonly enlisted to conduct intensive investigation of one or a few educational settings (Hayes, 2006; Frederick, 2012). Case study is not a method in itself, but an approach to qualitative research in which researchers triangulate a variety of methods to get different viewpoints of a case. Case study approach has some limitations, but is nonetheless useful for my research for several reasons.

Case study approach is sometimes criticized because its inductive, qualitative methods make positivist scientists uncomfortable, and its small sample sizes can make generalizing more difficult than in larger, more controlled studies (Hayes, 2006). My goal is not to definitively determine effectiveness of TMP tools. Rather, it is to explore the effectiveness of these tools within the rich context of a class setting where variables are too numerous and complex to isolate and control, definitely within the scope of my Master’s thesis, and perhaps even with unlimited time and resources.

The fields that use case study approach offer guidelines for studying an environment in which I am also a participant (as an instructor). Social science has a long history of rigorous participatory research in the form of participant observation (Clifford & Marcus, 1986; Fox, 1991; LeCompte & Schensul, 1999), as does education science in the form of instructors’ assessments of their students’ learning (Ash & Clayton, 2009; Heritage, Kim & Vendlinski, 2007; Nicol & Macfarlane-Dick, 2007; Stull, 2011).
Finally, a case study approach lends itself well to conveying knowledge to my intended audience: sustainability instructors looking for support, ideas, and resources to design or improve their own PPBL courses. Using PPBL to teach key competencies in sustainability is relatively new to many instructors who must negotiate common challenges to designing, teaching, and evaluating this kind of teaching and learning. As Hayes (2006) writes, “Case studies help to confirm for others that they are not alone in their struggles and that others share their experiences, struggles, conflicts and dilemmas.”

Two undergraduate ASU sustainability classes were selected for my study. One class is a 100-level honors section of an introductory sustainability and urban planning class, in which 15 first-year students conducted projects on biophilic design in different locations in the Phoenix Metro Area. The other class is a 400-level capstone workshop in which 11 senior students conducted projects on urban gardening, food waste, and sustainable building in collaboration with a community partner. This research was approved by the Arizona State University Office of Research Integrity and Assurance. Documentation can be found in Appendix E.

These classes were chosen because many of their design components (goal, learning objectives, teaching and learning activities, and evaluation techniques) are similar, though adjusted for project topics and student competence at progressive levels of the program (100 vs. 400), which contributes some amount of control to my study. First, classes are offered through the ASU School of Sustainability meaning that they are positioned in the same problem-based, solution-oriented sustainability context. Second, both engage a PPBL approach; students complete semester-long group projects in teams.
of 3-4. Teams are given a research problem and objective (more structured at the 100 level, less at the 400 level), and varying degrees of responsibility for designing and managing projects (more in 400 level and less in 100 level). Third, instructors in both take on a facilitating role, becoming a “guide on the side” who scaffolds students learning rather than “sage on the stage” who controls it as PBL instructor Mark Henderson explains (Henderson, personal communication) (more scaffolding at the 100 level and less at the 400 level). Syllabi, rubrics, and lectures communicate to students how PPBL works and expectations of students in PPBL settings, which is especially important since few students have experienced PPBL before. Fourth, teams in both classes were introduced to the same five TPM tools throughout the semester. All tools were housed on Blackboard sites and students were reminded periodically where to find them. Some of the tools were featured in class activities and assignments (work plan, code of collaboration, methods selection worksheet), while others were not (teamwork guidebook and meeting agenda and notes). Finally, both classes used formative techniques to assess (collect meaningful data about) and evaluate (determine effectiveness and extent of) teaching and learning. Students assess self- and peer- performance in the middle of the semester and at the end. Instructors assess the presentations and deliverables students’ produce throughout the semester. Additionally, students completed a formative course evaluation survey on the five TPM tools (See instrument in Appendix F).

The three assessments described above provide data for my study. I will analyze this data using a series of sub questions and descriptive codes. A code is a word or short phrase corresponding to a concept or other predetermined category used to organize and
assign meaning to qualitative data (Saldana, 2012). Codes for this study were initially derived from my hypothesis and expanded through inductive analysis. This analysis will enable me to evaluate the effectiveness of TPM tools in sustainability classes at 100 and 400 levels, explore factors in their effectiveness, and consider how instructors can improve their effectiveness in future sustainability courses.

**Case Profiles**

**100 level.** Sustainable Cities Honors Section is a 100-level honors section of approximately 15 students. It is part of the first sustainability class at Arizona State University (ASU), which introduces approximately 1000 students a year to basic concepts in sustainable urban planning and design (Frederick, 2012). Each semester, the honors section meets weekly to conduct semester-long projects in order to explore and apply class concepts in a real-world context. The session is typically designed and taught by a teaching assistant.

The Spring 2013 Honors Session topic is biophilia and biophilic design in Phoenix. This topic arose from a partnership between Dr. Pijawka and Dr. Timothy Beatley, director of the Biophilia Research Project at the University of Virginia School of Architecture. Dr. Beatley recently added Phoenix to 10 international cities in which he studies biophilia – human’s affinity for living things – and biophilic design – design that takes human’s need for nature into account (Beatley, 2012). He provides external advising to the class, as well as an audience to vet students’ final projects at the end of the semester.
The honors section uses problem- and project-based learning (PPBL) approach to teaching and learning. Key elements include a focus on specific sustainability problems, goal of developing a specific output through project work, collaboration, student self-directed learning, instructors’ role as coaches who support students’ self-directed efforts.

The class is designed to teach students a variety of learning objectives related to the topic of biophilic urban design, basic skills and abilities related to interpersonal and strategic competence in sustainability, as well as the basic steps of research and components of a research project. By the end of the class, students will be able to:

- Define biophilia and biophilic design,
- Explain why biophilic design might or might not be a solution option for specific sustainability problems that impact Phoenix.
- Use indicators to assess and evaluate biophilia and biophilic design
- Be familiar with teamwork and project management tools and be able to articulate and constructively critique their value, and
- Conduct group project work successfully using providing tools and / or finding or developing additional tools.

Students work in teams of 3-4 to study a specific site in the Phoenix metro area, such as The McDowell Sonoran Preserve, the Maple Ash Neighborhood, or Encanto Park. Each team explores how people connect with nature in this place, challenges to connecting with nature due to the nature of a desert city, and what lessons these parks, preserves and neighborhoods offer for integrating sustainability and biophilic design. Teamwork, meetings with Dr. Beatley and community contacts, fieldtrips,
designing and develop a panel discussion, and virtual presentations provide structured opportunities for learning. Students are provided with the 5 TPM tools to support their projects. Students are evaluated by instructors, peers, and selves in terms of participation, teamwork, and quality of their project outputs.

Each team creates a short research paper and a digital product (video, slideshow, GIS map, etc.) documenting their findings and teams collaborate to design and facilitate a Student Panel Presentation to the lecture section of the Sustainable Cities course. The impact of this class is mostly on student participants, who take knowledge, skills, and attitudes learned here to higher level classes, where they will be better prepared to participate successfully in sustainability research and project work in PPBL settings.

400 level. Sustainability Solution Options Capstone Workshop is a 400-level capstone class of 11 students and is designed and taught collaboratively by sustainability graduate students with support from sustainability faculty. Graduate instructors work with professionals from business, non-profit, or public sectors in the Phoenix Metro Area to identify local sustainability challenges, develop a project proposal, and recruit undergraduates to take on the project through the class. The overarching topic of the class is conducting collaborative sustainability research; the specific topics of team projects include urban gardening, composting food waste, and designing sustainable buildings.

The workshop uses problem- and project-based learning (PPBL) approach to teaching and learning. Key elements include a focus on specific sustainability problems, goal of developing a specific output through project work, collaboration, student self-directed learning, instructors’ role as coaches who support students’ self-directed efforts.
While this approach is identical to the one used in the Sustainable Cities Honors Project, this class is very different because of the increased complexity of the project, increased student responsibility for designing and conducting project, decreased teach scaffolding in terms of assignments and project structure, and increased instructor role as mentor rather than teacher.

The class is designed to teach students a variety of learning objectives related to the topics of individual team projects, as well as, conducting rigorous sustainability research and professional project work. By the end of the class, students will be able to:

- Demonstrate strong interpersonal and strategic competence to work, lead, and communicate within a team environment, identify and undertake the steps of co-designing and collaborating on sustainability projects with specific clients/stakeholders, and Examine effectiveness of self-direct learning through self-reflection and peer assessment of a task or project (i.e. objectives, process), sustainability competencies, and how you learn.

- Apply and be able to explain steps in sustainability research design (problem identification, goal/objective setting, work plan, data collection, assessment/evaluation, conclusion) in order to communicate what you did and why in a professional academic context.

- Be able to articulate research, project work, outputs, and learning outcomes on a resume in order to communicate what you did and why in a professional business context.

Students work in teams of 3-4 on the project they were recruited for, mentored by
the instructor who designed it. Students engage with the projects’ community partners to analyze sustainability problems, develop sustainability visions, and help create solution-options and strategies for change. Students are provided with the 5 TPM tools to support their projects. Students are evaluated by instructors, peers, selves, and community partners in terms of participation, teamwork, and quality of their project outputs.

Each team produced a deliverable and presents it to their community partner, include a building design for a start-up sustainability retreat company, an analysis of local restaurants’ barriers to composting food waste for a start-up composting company, and a proposal for creation and maintenance of an urban garden for the university. Each student creates a portfolio that highlights skills and products developed through the class. The impact of the class is shared between undergraduate students who develop knowledge, skills, experience, and a portfolio to take with them when they graduate; community partners who get a useful product and an opportunity to develop sustainability knowledge through the partnership; and graduate students who gain skills and experience designing and teaching problem- and project-based learning in sustainability.

Hypotheses

Which TPM tools were most effective in the 100-level sustainability class? I anticipate that the Work Plan will be most effective tool at the 100 level. This class requires students to work in teams to complete a project throughout the course of the semester. Many of these students are in their first year of the program and not have completed projects of this caliber before. Because work plans can help students organize a project into manageable steps, and assign tasks and due dates, I anticipate that a Work
Plan will be most effective at helping them complete and learn from project work.

**Which TPM tools were most effective in the 400-level sustainability class?** I anticipate that Meeting Agenda and Notes will be the most effective tool in the 400-level class. This class requires weekly team meetings and frequent meetings with community partners. Because Meeting Agenda and Notes can structure and organize meetings and provide easily accessible record of decisions made and tasks assigned, I anticipate that it will be the most effective tool in helping them complete and learn from project work.

**What factors contributed to effectiveness?** I anticipate that three main factors will contribute to effectiveness of a tool at both levels. 1) Integration of tool into activities and assignments (Biggs, 2001), 2) Whether or not students had used tools before, and 3) Relevance of tool for completing projects at given level of undergraduate education (Brundiers, et al., 2010; Pijawka, 2013).

**How can instructors improve the effectiveness of TPM tools?** I anticipate that three key suggestions for how instructors can improve effectiveness of TPM tools will emerge from analysis: 1) Make students more aware of tools provided and their potential value via class lectures, activities, Blackboard Site, and syllabus, 2) Incorporate all tools into class through activities that teach students how use them, and 2) Select tools that align with students’ competence and project requirements at a given level.
RESULTS

Unique data analysis procedures were used to answer each of my four research questions. Research questions one and two ask, “Which TPM tools were most effective in the 100- and 400-level sustainability classes?” Analysis of tool effectiveness was accomplished by considering whether or not the tool helped students complete their projects (Baninjarian & Abdullah, 2009) and whether or not the tool helped students achieve their courses’ learning objectives (Biggs, 2001). To determine if a TPM tool helped students complete projects, data from students’ course evaluation surveys, students’ self- and peer-performance evaluations, and instructor observations was compared to determine which tools students reported using, what the tools helped students accomplish in their projects, and whether or not using the tools corresponded to higher average teamwork scores. To determine whether or not a TPM tool helped students achieve course learning objectives, students’ top three course learning outcomes were examined along with students self reported competence development to see if use of TPM tools corresponded to learning outcomes related to key competencies in sustainability or class specific sustainability content.

Question three asks, “What factors influenced effectiveness of TPM tools in 100- and 400-level sustainability classes?” Analysis of factors in TPM tool effectiveness was accomplished by coding students survey responses to identify suggestive patterns. An initial set of codes was derived from my hypotheses; each code corresponded to a factor (integration, prior use, and relevance) that I hypothesized influenced effectiveness of TPM tools. The code set was then expanded through inductive research, as initial coding
of 100- and 400-level survey responses revealed additional factors that I had not considered, and used to identify patterns warranting further analysis.

Finally, question four asks, “How can sustainability instructors improve effectiveness of TPM tools in other sustainability classes?” Analysis of ways to improve effectiveness of the five TPM tools was accomplished through a similar coding process. Codes were developed based on suggestions made by more than one student, as well as additional hypothesis identified through inductive analysis. These codes were then applied to survey responses to identify patterns in suggestions or implications, of which the most frequently observed were explored through further analysis.

The following sections explore results of data analysis related to each of my research questions described above. *TPM tools at the 100 Level* explores which TPM tools students used most and how they used them, which tools were most effective in the Sustainable Cities Honors Section, factors in tool effectiveness at this level, and ways that instructors can improve their effectiveness. *TPM Tools at the 400 Level* does the same for TPM tools used in the Sustainability Capstone Workshop. Finally, the *Conclusion* summarizes results and highlights similarities, as well as differences in TPM tool use, effectiveness, factors in effectiveness, and ways to improve effectiveness at different levels of a sustainability program.

**TPM tools at the 100 level**

**Tools Used.** Work plans and meeting agenda and notes were the most commonly used TPM tools in the 100-level Sustainable Cities Honors Section. As shown in Figure 2, ninety percent of students used work plans, seventy-five percent used meeting agenda
and notes, forty percent used methods selection worksheets, and ten percent used a teamwork guidebook.

Figure 2. Percentage of Students Who Used Each TPM Tool in the 100-level Class.

Almost all 100-level students a work plan, which is designed to enable teams to develop project goals, structure work throughout the semester, and stay on track. One student explained that a work plan helped the team “develop long term goals for how we hoped to proceed with completion of the project and personal deadlines we wanted to meet. This made it easier for the team to stay on schedule and not fall behind with work.” Another student stated that a work plan provided “the structure needed to efficiently work through meetings in a timely manner. Furthermore, it provided the template necessary for effective collection of the individual parts for the final paper.” A third noted that a work plan allowed the team to “view the semester and project as whole, with each deadline clearly laid out. We were able to continually look at this when we needed to look ahead at what was coming next, or look back at what was already done.”

Three quarters of students used meeting agenda and notes template, which are designed to enable teams to hold timely, efficient meetings outside of class, keep track of
decisions, and save meeting time to deal with unforeseen issues. One student noted that
the tool made “meetings go much faster as we stayed on topic.” Another student
explained that the tool helped the team allocate “total amount of time for meetings and
[was] a means of maintaining the meetings according to set amount of time. This allowed
for time gaps [in which to deal with] unexpected delays.”

Effective Tools. Work plan and meeting agenda and notes were the most
effective tools in the 100-level Sustainable Cities Honors Project. As described above,
they enabled students to collaborate with each other to complete their projects. Students
did not explicitly mention that any of the tools contributed to successful collaborations
with community partners or instructor. However, as an instructor I found it much easier
to provide guidance to teams who maintained work plans, because I could use the teams’
plans to quickly ascertain who was responsible for each task, what tasks had been
accomplished, and what tasks remained.

In addition to helping students complete projects, work plans and meeting agenda
and notes also helped students achieve course learning objectives related to interpersonal
and strategic competence in sustainability. Nearly all students (10/11) explained that the
class helped them develop interpersonal competence and a majority (8/11) cited
teamwork-related learning outcomes. For example one student wrote that he, “was able to
develop interpersonal skills for working in a team setting, such as giving other team
members jobs to be done for an assignment and motivation [to complete them].” Class
activities and tools were ranked by students as the most and second most useful class
components in helping them develop this competence, while they rated readings and
lectures least and second least useful, respectively. Students ranked work plans or meeting agenda and Notes (8/12) as the most useful TPM tools for helping them developing Interpersonal Competences.

Over two-thirds of students (7/10) explained that the course helped them develop strategic competence, all of whom reported project management related learning outcomes. Again, students ranked class activities (11/12) and tools (7/12) as the most and second most useful class components in helping them develop this competence, while they rated readings and lectures least and second least useful, respectively. Students ranked Work Plan and Methods Selection Worksheet as the most useful TPM tools for helping them develop strategic competences.

Half of the students reported that learning how to use one of the TPM tools was an important learning outcome of the class, indicating that the tools helped students achieve the courses’ interpersonal and strategic competence learning objectives related to teamwork and project management. For example learning “how to complete a long term research project by using a [work plan]” was an important learning outcome of the class for one student while learning how to create “team meeting agendas and goals for each meeting” was an important learning outcome for another.

For a few students, learning how to use TPM tools as a means to an end in sustainability projects was an important learning outcome. One student wrote, “To make a difference in the field of sustainability, one must have the skills, knowledge, and attitudes necessary to analyze, evaluate, and make achievable what they hope to…do. The tools in this class helped us develop these skills.” However, achievement of learning
objectives was not universal due to problems with teamwork and project management: another student wrote, “Unfortunately, a lack of team member interest and participation in various aspects of the project caused added anxiety for me, reduced the quality of work, and made for a poorly done project that did not serve to teach us the objectives of the course and the project.” This comment came from a student who was the only team member to actively use most tools.

While it is clear that the tools helped students achieve interpersonal and strategic competence-based learning objectives, it is unclear if they also helped student achieve learning outcomes related to other key competencies or sustainability content. Furthermore, it was unclear if using these tools directly led to better teamwork. Table 2 compares use of the five TPM tools - work plans (WP), meeting agenda and notes (MA), code of collaboration (CC), methods selection worksheet (MW), and teamwork guidelines (TG) - to students’ teamwork scores. The number of x’s in columns two through five indicates the number of students in each team who used each tool. The Total Use column indicates the number of students within each team who used one of the tools, and the Total Tools column indicates the number of tools used by at least one person in each team. Teamwork scores for each team are calculated by adding the average score each student in the team gave themselves and their peers.
Table 2

*Teamwork Scores and Use of TPM Tools at the 100 Level*

<table>
<thead>
<tr>
<th>Team</th>
<th>WP</th>
<th>MA</th>
<th>CC</th>
<th>MW</th>
<th>TG</th>
<th>Total Use</th>
<th>Total Tools</th>
<th>Teamwork Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>x</td>
<td>xx</td>
<td>x</td>
<td></td>
<td></td>
<td>4</td>
<td>3</td>
<td>160</td>
</tr>
<tr>
<td>2</td>
<td>xxx</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
<td></td>
<td>8</td>
<td>4</td>
<td>170</td>
</tr>
<tr>
<td>3</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>4</td>
<td>3</td>
<td>175</td>
</tr>
<tr>
<td>4</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td></td>
<td>6</td>
<td>4</td>
<td>176</td>
</tr>
<tr>
<td>5</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>xx</td>
<td></td>
<td>7</td>
<td>4</td>
<td>166</td>
</tr>
</tbody>
</table>

It was unclear if the number of TPM tools used by a team, or the number of students in a team who actually used them, corresponded to higher average teamwork scores in students’ self- and peer-evaluations; the two teams that used the least number of TPM tools (3) received the highest and lowest teamwork scores. Several unobserved factors might be skewing this data. For example, students in the high scoring team used additional TPM tools beyond the ones provided by the instructor. Also, self- and peer-evaluations were conducted at the middle of the semester before many of the teams reached rocky “storming” or “norming” phases, where they might (or might not) overcome teamwork challenges (Tuckman, 1964). Finally, about half of students’ self and peer evaluations did not align with instructor observations of students’ actual project participation and contribution; scores seemed to be dashed off in a hurry and were not supported with evidence from examples. This is a common phenomenon, especially in students who have not been taught to engage in structured self-reflection or who have not developed enough experience with formative assessment techniques that require them to justify their self and peer evaluations (Ash & Clayton, 2004). Thus the teamwork scores may not reflect teamwork accurately. Furthermore, the small sample size and
fact that not all students from each team participated in my study also made it difficult to identify patterns in use of tools, teamwork scores, and project grades.

While there is not a clear link between tool use and teamwork scores and project grades, I did observe that teams who used work plans and agendas consistently experienced fewer teamwork and project management issues, and less time struggling to resolve issues that did arise. These teams had more time to work on the content (rather than process) components of their projects and thus more time and energy to focus on achieving content-related learning objectives.

**Factors in Effectiveness.** One factor in the effectiveness of work plans and meeting agenda seemed to be whether or not students actively used them. This is not surprising since these tools are considered invaluable in many levels of education, academic disciplines, and professional fields. The students for whom these tools were not effective often did not use them to their full potential. For example, one student explained, “We wrote some very basic, overview type things… but team members didn't look at/use these [meeting agenda and notes] documents after they were finished being typed.”

Another factor in effectiveness of these tools may be prior use. If a student had used a tool prior to the class, their teams were more likely to use it effectively in the Sustainable Cities honors section. Table 3 illustrates which of the five TPM tools - work plans (WP), meeting agenda and notes (MA), code of collaboration (CC), methods selection worksheet (MW), and teamwork guidelines (TG) - students used during Spring 2013 and which they had used prior to the class. The number of teammates who used each tool is indicated by an x in the Use (U) and Prior Use (P) columns.
Table 3

Use and Prior Use of TPM Tools at the 100 Level

<table>
<thead>
<tr>
<th>Team</th>
<th>WP</th>
<th>MA</th>
<th>CC</th>
<th>MW</th>
<th>TG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
<td>U</td>
<td>P</td>
<td>U</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>xx</td>
<td>xxx</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
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<tr>
<td>3</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>4</td>
<td>x</td>
<td>xx</td>
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<td>x</td>
<td>x</td>
</tr>
<tr>
<td>5</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

A third factor in the effectiveness of work plans and meeting agenda and notes at the 100 level was whether or not they were integrated into class activities and instructor mentoring. While the five TPM tools were presented to students in class, were explained briefly, and students were reminded of them periodically throughout the semester, not all of the TPM tools were incorporated into activities and mentoring. More students reported using TPM tools that were integrated into class as part of an activity or that were targeted by instructor in team or one-on-one mentoring. Table 4 shows the numbers of students who used each tools, and which tools were incorporated into class activities and instructor mentoring.

Table 4

Activities, Mentoring, and Use of TPM Tools at the 100 Level

<table>
<thead>
<tr>
<th>Tool</th>
<th>Student Use</th>
<th>Class Activity</th>
<th>Mentoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work Plan</td>
<td>10</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Agenda and Notes</td>
<td>10</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Code of Collaboration</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methods Selection Worksheet</td>
<td>5</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Teamwork Guidebook</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
One student explained that during class activities, “the instructor made [the tools] useful by going over them with us and showing us how to properly utilize them to their full potential.” Another student noted, “The meeting agenda and notes that I filled out with the instructor was the most helpful because I included things that I hadn't realized needed to be included.”

**Ideas for improving effectiveness.** Several methods for improving the effectiveness of TPM tools in 100-level sustainability classes emerged from my research; some came directly from students and some from my own insight as I analyzed students’ suggestions and considered applicable literature. Students indicated that introducing tools earlier in the semester, incorporating tools into class activities and assignments, and helping them pick or develop tools relevant to their project work and resonant with personal choice may improve effectiveness of TPM tools at the 100 level. Further analysis suggests that polling students at the beginning of the semester to find out what TPM tools they have previously used could help instructors design activities and assignments around unfamiliar tools, and helping students develop a deep understanding of teamwork, project management, and the key competencies in sustainability might also help instructors improve effectiveness of TPM tools.

Introducing tools earlier in the semester might increase the effectiveness of TPM tools in 100-level sustainability classes, helping students take more responsibility for their projects and engage more actively in processes of team collaboration and project management. PPBL instructors often strive to introduce course material to students “just in time” so that students are not overwhelmed by too much content at the beginning of a
project and develop a sense of need of the material for themselves, which facilitates their experiential learning (Barron, et al. 1998). This may work for instructors who can work closely with a small number of students, but for those responsible for more students, or perhaps where basic TPM tools are concerned, introducing a basic set of tools at the beginning of a 100-level class might be more effective.

Incorporating TPM tools into activities and assignments may also increase their effectiveness at the 100 level. One student wrote, “The instructor could make these tools more useful by…allowing more class time for students to utilize/work on them. For example, when we were creating a work plan/agenda, my group did not have enough time to finish and, therefore, never used this tool to its full potential.” In this case, one activity was not enough to help the student grasp how to use the tool and feel confident to use it with their team. Another student suggested that “making these completed documents due as assignments would ensure that groups were doing them, it could help hold teams more accountable, and it could also help teams realize what is expected of them and what needs to be done for the project.” The student felt that they were not able to hold teammates accountable for using TPM tools effectively and that this could be achieved if the instructor made use of the tools required through class assignments. PPBL strives to engage students in self-directed learning, but this does not mean that class is a free-for-all. Strategic activities and assignments designed to engage students in learning knowledge and skills to accomplish their projects can provide a structure for self-directed learning.

Determining which tools students have not used before and focusing class activities and assignments on how to use them may increase effectiveness of TPM tools.
Recent research on key competencies in sustainability notes that it is important to take students disciplinary background into account so that instructors can teach to student’s level of comprehension (Musgrove, et. al., 2012). Since many of the 100-level students had previously used some form of a work plan or meeting agenda and notes, they might have benefitted from more class activities and assignments on other tools.

Helping students develop a deep understanding of what constitutes teamwork and project management may also improve effectiveness of TPM tools. When asked what tools they used to support teamwork and project management, many students mentioned communication tools like email and Google Chat and communication spaces like Dropbox and GoogleDocs. This suggests that at the 100 level, students’ conceptions of what constitutes good teamwork and project management is somewhat limited to communication. Communication does not automatically lead to better products and learning outcomes; quality and outcomes of and how decisions are stored in collective team memory are just a few other considerations in teamwork and project management. Helping students understand how teamwork and project management are linked to sustainability problem-solving competence may help students understand TPM tools as a means to an end (Barron, 1998).

Finally, introducing the tools as a toolkit from which students can select depending on their project, their team, and their personal preferences may be another way to improve effectiveness of TPM tools at the 100 level. One student reflected,

I don’t think it’s so much what the tools are [that makes them useful] but the kind of person using them. I personally wouldn’t really use any of these again, aside from the Code of Collaboration, simply because I have other methods of preparing and executing a research project that work well for me…everyone has their own approach to learning and there isn’t one answer method of doing things.
In fact using “tools” or “methods” that don’t correspond to a certain person could possibly slow down or take away from a person’s research. This suggests that helping students understand TPM tools not in terms of what they are or look like, but in terms of what they are designed to accomplish, may help students pick effective tools that match the needs of their projects, teams, and personal preferences. This may also help avoid stifling students’ creativity as seemed to occur with one student who wrote, “The tools used in this course were very effective in providing a consistent means of organizing for all groups and team members. However, at times I felt that we clung too strongly to form, rather than letting things unravel a bit more naturally.” To paraphrase another student, what use of the TPM tools aims to accomplish is important for sustainability projects; the tool is just a vehicle and if students can accomplish those things with different tools its okay to use that tool instead.

**TPM tools at the 400 level**

**Tool use.** Codes of collaboration and work plans were the most commonly used TPM tools used by students in the 400-level Sustainability Capstone Workshop. As shown in Figure 3, almost ninety percent of students used codes of collaboration, seventy-five percent used work plans, sixty percent used meeting agenda and notes, and twenty-five percent used methods selection worksheets and teamwork guidebooks.

![Figure 3. Percentage of Students who used TPM Tool in the 400-level class.](image-url)
Almost all 400-level students used codes of collaboration, which enabled them to set clear expectations for performance within teams and helped some students deal with teamwork issues that arose. One student reported that the tool helped “set [teamwork] expectations from the start.” Another explained that “the code of collaboration was really helpful, because when there were minor issues [with teamwork], we could refer to [it];” and a third added, “We used this tool to set team ground rules and to hold team members accountable.” Although most students found the tool useful, one commented that it was “barely useful if group is experienced” and added that he thought his team was flexible enough to work together without one.

Seventy-five percent of students in the 400-level class used work plans, which enabled them to plan projects, assign tasks, and stay on track with project work throughout the semester. One student reported that the tool enabled his team to determine and remember “who is assigned to what task.” Another pointed out that it “helped us keep on track as the project progressed.” A third explained that it “…helped us with keeping up with [tasks] but also helped to give us an overall timeline;” and a fourth noted that the work plan was “invaluable for setting reasonable milestones.” Of note is the fact that about half of the students used Gantt Charts in addition to, or instead of, the work plan templates provided for them; essentially, all students used some kind of work plan. Gantt Charts are work plans that visually display a project’s tasks on overlapping timelines. Gantt Charts were not introduced to the class by an instructor, but by two students who then helped their peers learn how to create them.
Effective tools. Work plans were the most effective TPM tool in the 400-level class, followed by codes of collaboration and meeting agendas and notes. As at the 100 level, active use of a tool generally indicated that tool’s effectiveness. Not all students chose to use all tools, but the ones they did use helped them complete project work as indicated in the description of how students used each tool above.

Work plans, codes of collaboration, and meeting agendas and notes also helped students achieve course learning objectives related to interpersonal and strategic competence in sustainability. Over half of respondents (5/7) reported that the class helped them develop interpersonal competence, and half (4/8) described teamwork-related learning outcomes. Class activities and tools were ranked by students as the most and second most useful class components in helping them develop this competence, and lectures and readings were ranked second least and least useful, respectively. Students ranked codes of collaboration or meeting agendas and notes (7/8) as the most useful TPM tool for helping them developing interpersonal competence.

A majority of students (6/8) also reported that the course helped them develop strategic competence, although less than half described project management-related learning outcomes. Work plans were clearly ranked the most useful tool for helping students develop this competence; methods selection worksheets and codes of collaboration tied for second. Each student ranked readings, lectures, activities, and tools in terms of their usefulness is helping them develop this competence. Although more students (3) ranked readings the most useful, responses were pretty well divided between other components, revealing a lack of consensus on second, third, and least useful.
While students reported that work plans, codes of collaboration, and meeting agendas and notes helped them achieve interpersonal and strategic competence-based learning objectives, learning how to use TPM tools did not figure into important learning outcomes as it did for 100-level students. Instead, 400-level students listed learning outcomes such as “how to collaborate professionally within a group,” “[dealing with] bureaucracies behind sustainable change,” and “project management roles.” At the 400 level, consequently, use of TPM tools seemed to help students achieve learning outcomes related to teamwork and project management rather than be the learning outcomes.

It was unclear if use of TPM tools at the 400 level led directly to better teamwork. Table 5 compares use of the five TPM tools to students’ teamwork scores. The number of x’s in columns labeled work plan (WP), meeting agenda and notes (MA), code of collaboration (CC), methods selection worksheet (MW), and teamwork guidelines (TG) indicates the number of students in each team who used each tool. The Total Tools column indicates how many tools were used by at least one person in each team. Teamwork scores for each team are calculated by adding the average score each student in the team awarded themselves and their peers.

<table>
<thead>
<tr>
<th>Team</th>
<th>WP</th>
<th>MA</th>
<th>CC</th>
<th>MW</th>
<th>TG</th>
<th>Total Use</th>
<th>Total Tools</th>
<th>Teamwork Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>xx</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td></td>
<td>7</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>xxx</td>
<td>xxx</td>
<td>xxxx</td>
<td></td>
<td></td>
<td>10</td>
<td>3</td>
<td>56</td>
</tr>
<tr>
<td>3</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td></td>
<td></td>
<td>6</td>
<td>3</td>
<td>57</td>
</tr>
</tbody>
</table>

Table 5
Teamwork Scores and Use of TPM Tools at the 400 level
400-level students engaged more constructively in self-and peer-evaluation than students at the 100 level; they provided more detailed justification for their evaluation scores, which were also more likely to correspond with scores given by their peers. However, the small sample size and the fact that not all students from each team participated in my study made it difficult to identify patterns in use of tools and teamwork scores.

**Factors in effectiveness.** Active use of the TPM tool seemed to be a factor in tool effectiveness at the 400 level, as it was at the 100 level. Few students reported that a tool was unhelpful if they used it. Students who did indicate a tool was not useful may have been overconfident in their interpersonal skills. For example, one student indicated that a code of collaboration was not helpful because their team was “flexible enough to work together” without it. However, teammates rated this student’s teamwork performance very low and later cited the team’s code of collaboration as helpful for “setting ground rules and holding team mates accountable.”

Prior use may have been a factor in effectiveness of work plans and meeting agendas. Table 6 illustrates which of the five TPM tools – WP, MA, CC, MW, and TG - students used during Spring 2013 and which they had used prior to the class. The number of students who used each tool in each of the five teams is indicated by an x in the Use (U) and Prior Use (P) columns.

<table>
<thead>
<tr>
<th>Team</th>
<th>WP</th>
<th>MA</th>
<th>CC</th>
<th>MW</th>
<th>TG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
<td>U</td>
<td>P</td>
<td>U</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 6

*Use and Prior Use of TPM Tools at the 400 Level*
As Table 6 shows, prior familiarity with a tool might be a factor in the use and, by proxy, effectiveness of work plans and meeting agenda/notes, but it does not seem to be a factor in the use/effectiveness for the other tools. For example, only one student had used a code of collaboration before the class, but eight reported using it during the class, and while two students reported using a teamwork guidebook before class, none reported using it during the class.

A possible third factor in the effectiveness of work plans, codes of collaboration, and meeting agendas and notes at the 400 level was how they were integrated into the course activities. While all five of the tools were presented to students in class and briefly explained, and students were reminded of them periodically throughout the semester, not all of the TPM tools were incorporated into activities. More students reported using TPM tools that were integrated into class as part of an activity. Table 7 shows the numbers of students who used each of the five TPM tools and which tools were incorporated into class activities.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Student Use</th>
<th>Class Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work Plan</td>
<td>7</td>
<td>x</td>
</tr>
<tr>
<td>Agenda and Notes</td>
<td>6</td>
<td>x</td>
</tr>
<tr>
<td>Code of Collaboration</td>
<td>8</td>
<td>x</td>
</tr>
<tr>
<td>Methods Selection Worksheet</td>
<td>2</td>
<td>x</td>
</tr>
<tr>
<td>Teamwork Guidebook</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

The only tool not used by students – the teamwork guidebook – was the only tool not incorporated in class activities.
**Ideas for improving effectiveness.** Several possibilities for improving the effectiveness of TPM tools in 400-level sustainability classes emerged from my research, some directly from students and some from my own insight as I analyzed students’ suggestions while considering literature on PPBL and sustainability education. As Table 8 shows, students indicated that introducing TPM tools earlier in the class or academic program, incorporating tools into activities and linking activities to projects, and helping students to pick or adapt tools to match their personalities and work preferences might improve effectiveness of the tools.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness</td>
<td>Whether or not students understood value of tools</td>
<td>2</td>
</tr>
<tr>
<td>Integration</td>
<td>How tool is integrated into class through activities and assignments</td>
<td>4</td>
</tr>
<tr>
<td>Relevance</td>
<td>Whether or not the TPM tools are relevant for completing projects at given level</td>
<td>3</td>
</tr>
<tr>
<td>Timing (class)</td>
<td>When in the semester instructors introduce students the TPM tools</td>
<td>3</td>
</tr>
<tr>
<td>Timing (curriculum)</td>
<td>When in the course of an undergraduate curriculum tools are introduced</td>
<td>2</td>
</tr>
<tr>
<td>Personality Match</td>
<td>Whether or not a certain tool or format of a tool resonates with a student user</td>
<td>4</td>
</tr>
</tbody>
</table>

In the 400-level class, students were anxious to get working on their projects. Tool effectiveness might be improved by presenting students with TPM tools earlier in the class through a series of activities, so that students are aware of what they have to work with, and then coaching students on how to select, find, and develop useful TPM tools.
A curriculum that introduces TPM tools earlier in the program might further allow students in higher level classes to spend less time learning about teamwork and project management and more time applying these skills to complete sustainability project work. One student suggested a sustainability methods and tools workshop immediately prior to the course; another suggested one earlier in the program.

Helping students link teamwork, project management, and TPM tools to sustainability problem solving competencies might also enhance tool effectiveness. Barron, et al. (1998) write, “One of the most important ways to scaffold open-ended projects is to help students … continually reflect on how and why their current activities are relevant to the overall goals (the big picture) of the project (p. 277).” Despite completing readings, listening to lectures, and discussing key sustainability competencies in class, about half of the students had trouble linking teamwork and project management to interpersonal and strategic competence. This finding is supported by insight from other sustainability instructors who introduce key competencies in sustainability into their classes and find they need to spend a significant amount of time helping students grasp the concept and what the competencies look like off the page (Sonya Remington Doucette, personal communication, March 1, 2013; Sada Gilbert, personal communication, March 28, 2013). Since students found activities to be the most useful class components, perhaps activities that help students reflect on what teamwork and project management look like, how they relate to key competencies in sustainability, and how TPM tools can help students complete sustainability project might be useful.
Summary

Table 9 summarizes the results detailed in the sections above.

<table>
<thead>
<tr>
<th>Tools used most</th>
<th>100 level</th>
<th>400 level</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Work plan</td>
<td>-Code of collaboration</td>
<td></td>
</tr>
<tr>
<td>-Meeting agenda</td>
<td>-Work plan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Meeting agenda and notes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Most effective tools</th>
<th>100 level</th>
<th>400 level</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Work plan</td>
<td>-Work plan</td>
<td></td>
</tr>
<tr>
<td>-Meeting agenda</td>
<td>-Code of collaboration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Meeting agenda and notes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factors in effectiveness</th>
<th>100 level</th>
<th>400 level</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Active use</td>
<td>-Active use</td>
<td></td>
</tr>
<tr>
<td>-Prior use</td>
<td>-Integration into activities</td>
<td></td>
</tr>
<tr>
<td>-Integration into activities</td>
<td>-Tool relevance</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To increase effectiveness</th>
<th>100 level</th>
<th>400 level</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Poll students on prior use</td>
<td>-Introduce tools earlier (in class)</td>
<td></td>
</tr>
<tr>
<td>-Introduce tools earlier</td>
<td>-Introduce tools earlier (in program)</td>
<td></td>
</tr>
<tr>
<td>-Incorporate tools into activities</td>
<td>-Incorporate tools into activities</td>
<td></td>
</tr>
<tr>
<td>-Incorporate tools in assignment</td>
<td>-Connect tool to sustainability problem solving</td>
<td></td>
</tr>
<tr>
<td>-Connect tool to sustainability problem solving</td>
<td>-Coach students to pick, find, or develop tools relevant for project, team, and personal preferences</td>
<td></td>
</tr>
<tr>
<td>-Cultivate understanding of teamwork and project management</td>
<td>-Introduce tools in a toolkit</td>
<td></td>
</tr>
</tbody>
</table>

Analysis reveals many similarities in tool use, tool effectiveness, and strategies for improving tool effectiveness in the two different levels of an undergraduate sustainability program. For example, work plans and meeting agenda notes helped students to complete projects and achieve learning objectives at both levels. Active use of a tool (by more than one team member) and whether or not a tool was integrated into class activities influenced effectiveness at both levels. Introducing tools earlier in the semester, incorporating tools into class activities, and helping students connect what a
tool can help them accomplish with what sustainability problem solving requires may improve effectiveness of tools at both levels.

Several differences were identified as well. For example, codes of collaboration played a much larger role in helping 400-level students complete projects and achieve learning outcomes than it did for 100-level students. Since prior use seemed to be a factor in tool use at the 100 level (and tool use was a factor in effectiveness), polling students to determine which tools they have used before might help instructors selectively design activities and assignments around unfamiliar tools, rather than familiar ones, in order to increase their effectiveness. Finally, at the 100 level, incorporating tools into assignments might help students learn how to use them, hold students accountable to their teammates, and consequently help students develop an understanding of what teamwork and project management look like. At the 400 level on the other hand, it may be more effective to help students learn to select, find, or develop tools that help them accomplish certain teamwork and project tasks and are relevant to specific sustainability project, team, and personal work habits. Finally, introducing TPM tools earlier in a sustainability program may enable students at the 400 level to spend less time learning how to use tools and more time using them to accomplish project work and achieve learning outcomes in capstone classes.

Several limitations of the study should be considered along with these results. First, qualitative analysis of this nature is often conducted by two people separately so that results can be compared and synthesized to shed light on reliability. However, due to
time constraints, analysis was conducted by only one person. Second, the small sample size and non-random selection of cases should be considered when generalizing these results to other classes in the program. Third, the fact that the version of PPBL used in the two classes studied is not part of a formal PPBL model but rather instructors’ attempts to apply evidence-based PPBL principles from a variety of models should be considered when generalizing results to other sustainability programs.
CONCLUSION

Sustainability science education strives to train students to be capable of tackling problems as diverse as climate change, poverty, biodiversity loss, obesity, and famine (Wiek, Withycombe, & Redman; 2011; Sarewitz, Clapp, Crumbley, Kriebel, & Tickner, 2012). This requires students to develop a unique suite of competencies in addition to basic ones (Barth, et al., 2007; Wiek, et al., 2011) that together enable students to study and develop solutions for sustainability problems (Kates, et al., 2001; van der Leeuw, Wiek, Harlow, & Buizer, 2012). Sustainability science education can be a powerful solution itself (Sterling, 2002; Row, 2007; Sipos, Battisti, & Grimm, 2008; AASHE, 2010; Brundiers & Wiek, 2011, Burns, 2011; Wiek, et al., 2011; Frisk & Larson, 2012), in which we design “learning as change…a creative and paradigmatic response to sustainability” (Sterling, 2002, p. 61 as cited in Burns, 2011, conclusion, para. 1).

In order for sustainability science education to have this change-making impact, sustainability instructors are increasingly designing and implementing PPBL to teach competencies for sustainability problem solving. TPM tools are an important part of teaching interpersonal and strategic competencies to undergraduate students through PPBL; these tools can help students complete projects and achieve teamwork and project management learning objectives, and they serve as a vehicle for other key competency- and content-based learning outcomes. However, little research has previously addressed which TPM tools are appropriate for various levels of sustainability programs, or how to implement them effectively.
This study attempted to lessen this gap by comparing TPM tool effectiveness in a 100-level sustainability class and a 400-level sustainability class. Research found that work plans and meeting agendas were the most effective TPM tools in the 100-level class studied, while work plans and codes of collaboration were most effective in the 400-level class. Common factors in effectiveness included active use of the tool by more than one student per team team and integration of tools into class activities. Introducing tools earlier in the course, incorporating tools into activities, and helping students link tools’ value to sustainability problem solving competence might improve effectiveness of tools at both levels. Polling students on prior use and incorporating tool use into project assignments may increase tool effectiveness at the 100 level. Introducing tools earlier in a sustainability program and coaching students to select, find, and develop relevant tools may increase effectiveness of TPM tools at the 400-level.

Study results can provide insight to instructors interested in designing PPBL sustainability classes, although the small sample size, restriction to one school, and the PPBL version utilized must be taken into consideration. Additionally, the results speak to the larger issue of the need for progressive curriculum models (Brundiers, et al., 2010) or step-wise approaches (Pijawka, et al., 2013) for sustainability education, and particularly key competency-based education. Without a progressive curriculum model, and with only a few empirical studies on PPBL tools use and effectiveness in various levels of a sustainability program, it will likely remain challenging for novice PPBL instructors short on time and resources to select or design appropriate tools and other material for their sustainability classes.
Some educational organizations are beginning to develop progressive curriculum models for teaching key competencies in sustainability. Others, like Maastricht University, Aalborg University, and even ASU’s School of Engineering, have developed progressive curriculums for teaching a variety of subjects through PPBL. Curricula from these organizations lay out courses such that learning outcomes of any class will build on those of preceding classes, avoiding repetitive teaching and ensuring that students graduate with promised learning outcomes. They also ensure that upper-level students have already learned basic concepts and skills that will enable them to participate fully in classes and workshops without requiring time-consuming introduction and scaffolding. A progressive curriculum designed to teach key competencies in sustainability through PPBL could provide guidance for instructors designing classes at different levels about what students have encountered before and will encounter later in a program, and consequently what materials – including TPM tools – are appropriate for teaching and learning relevant knowledge, skills, and attitudes at a given level.
References


APPENDIX A

TOOL: CODE OF COLLABORATION
Code of Collaboration Instructions

Your team’s code of cooperation should include actions and items that you have all agreed to that will allow your team to successfully work together. Consider how you will arrange to meet, work together, and importantly, how you will deal with any conflict that arises or with members that are not abiding by the Code of Cooperation. Consider these potential points:

Be respectful
- Value others’ opinions and suggestions.
- Do not let frustrations devolve into personal attacks.
- Communicate with campus and community stakeholders in a professional manner.

Be considerate
- Arrive to meetings on time. Communicate ahead if running late or need to miss.
- Listen actively; do not interrupt others or dominate discussions.
- Consider how your actions or words affect the progress and feelings of your team members and stakeholders.

Be collaborative
- Work together; help reduce redundancies by taking the time to share with the group.
- Challenge yourself and encourage others to explore new experiences and skills.
- Make sure you are attentive and engaged in meeting times. Do not remain silent.
- Set reasonable deadlines as a team; prepare individual and team deliverables on time.

Be available
- Check your email, Blackboard account, and other means of communication regularly so as not to hold up others’ progress. Respond in a timely manner (usually a day).
- Always send a short acknowledgement of receiving an assignment or question, even if you can’t answer immediately.

Be transparent
- Be willing to ask for feedback or help (from team, instructors, and stakeholders).
- Communicate how you feel in meetings in a constructive manner.
- Share with the team how you think project is progressing, and if you think something needs to be changed (format, roles, etc.).
Be Organized

- Agree on routes of communication and communication guidelines that work for everyone (ex: email, phone, blackboard, GoogleDoc, Facebook, communications log).
- Establish and specify team roles (ex: project, communications, data managers)
- Agree on methods for capturing, sharing, and working w/ data (GoogleDoc, Dropbox).
- Develop and actively update a project work plan.

Teams and community partners should also co-create a Code of Collaboration to guide interactions. This document should include actions and items that you have all agreed to that will allow you to successfully work together. Consider how you will arrange to meet and / or give and receive feedback, how you will approach the work involved for your project, how to collaboratively determine project objectives / goals / and outputs, and how you will deal with any conflict that arises or with members that are not abiding by the Code of Collaboration. In addition, you should include an overview of roles and responsibilities.

Code

- 
- 
- 
- 
- 
- 

Roles and Responsibilities

- Community Partners
- Student team

Communications

(Type? Times? Frequency? Team / Partner spokespeople?)

- 
- 
APPENDIX B

TOOL: MEETING AGENDA AND NOTES
Meeting #: date, location
Facilitator:

Note taker:

**Agenda:**
1. (Time) – Discussion Point
2. .....
3. .....

**Minutes:**
**Post Meeting Action Items:**

<table>
<thead>
<tr>
<th>No.</th>
<th>Action</th>
<th>Assigned To</th>
<th>Deadline</th>
<th>Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Decisions Made:**
- 

**Major Accomplishments:**
- 
- 

**Next Meeting:**
APPENDIX C

TOOL: WORK PLAN
Team Work Plan Template

Creating a Work Plan early on will help your team accomplish your research goals by breaking down what you need to do in order to accomplish these goals into a series of specific tasks, documenting task due dates and group members responsible for task or step, and providing a place for team members to document and monitor team progress. You can use the template below to create your own work plan. The key is to start with your research question and goal, and work backwards to list the tasks or steps that need to occur in order for you to accomplish your goal and answer your research questions.

**Question / Goals:**

| DATE | Task (responsible group member)  
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<tr>
<td></td>
<td>• Necessary Steps</td>
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APPENDIX D

TOOL: PICKING YOUR METHODS
Picking your research methods

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Info Needed</th>
<th>Method to use</th>
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<td>4</td>
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To: Charles Redman  
Wrigley Ha  

From: Mark Roosa, Chair  
Soc Beh IRB  

Date: 03/15/2013  

Committee Action: Exemption Granted  
IRB Action Date: 03/15/2013  
IRB Protocol #: 1303008950  

Study Title: Teaching Key Competencies in Sustainability through Problem- and Project-Based Learning: Tools for undergraduate teams  

The above-referenced protocol is considered exempt after review by the Institutional Review Board pursuant to Federal regulations, 45 CFR Part 46.101(b)(1).  

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects’ financial standing, employability, or reputation.  

You should retain a copy of this letter for your records.
Please answer the following evaluation questions to help your instructor improve SOS 111 / PUP 190 Honors Project or SOS 494 Capstone Workshop.

Remember that evaluation isn't just about reporting on how well you liked or didn't like a class – it is about providing constructive feedback to instructors that will help them improve it. This requires you to describe, explain, and provide examples and evidence that support your answers.

The survey includes 22 questions and takes 15-20 minutes. You are free to skip question, but please answer the questions in order.

1. What is your last name?

2. What class are you in?
   - [ ] SOS 111 / PUP 190 Honors Project
   - [ ] SOS 494 Capstone Workshop

3. In this class how successful were you in collaborating with the following people?
   - [ ] Team members
   - [ ] Instructor
   - [ ] Community partners or contacts

4. What made your collaborations successful or unsuccessful? Explain and give specific examples.

5. What are the three most important things you learned in this class?
   1. 
   2. 
   3. 

6. What tools did your team use to support collaboration and project work?
7. Which of the following tools did your teams use this semester? If you need to refresh your memory on what each tool looks like, check your class Blackboard site.

- [ ] Code of Collaboration
- [ ] Meeting Agenda and Notes
- [ ] Work Plan
- [ ] Picking Your Methods Worksheet
- [ ] Tips for Teams Booklet

Other (please specify)

8. Describe how you used each tool and what value they provide to your teams. Write N/A if you did not use the tool.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Description</th>
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<tbody>
<tr>
<td>Code of Collaboration</td>
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<tr>
<td>Meeting Agenda and Notes</td>
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<tr>
<td>Work Plan</td>
<td></td>
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<tr>
<td>Picking Your Methods Worksheet</td>
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<tr>
<td>Tips for Teams Booklet</td>
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<tr>
<td>Other</td>
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</table>

9. Were any of the tools not useful? Please explain.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Explanation</th>
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<tr>
<td>Code of Collaboration</td>
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<tr>
<td>Other</td>
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</tbody>
</table>

10. How could the instructor make these tools more useful?

[Blank space]

11. Can you imagine other tools that would be useful for student teams in this class? Give specific examples and explain how and why they would be useful.

[Blank space]
12. Have you used the following tools in other classes or professional settings? If so, list the class or setting, and explain how you these tools in them.

- Code of Collaboration
- Meeting Agenda and Notes
- Work Plan
- Picking Your Methods
- Worksheet
- Tips for Teams Booklet

13. What are the key competencies in sustainability? Define and explain why they are important.

Key competencies in sustainability are suites of knowledge, skills, and attitudes that enable students to collaboratively study and develop solution-options for life-threatening, long-term, complex, urgent, contested, place-based sustainability problems (Kates, et al., 2001; Barth, et al., 2007; Wiek, et al., 2011; Leeuw, 2012).

- Systems thinking competence is about thinking big picture. It is the ability to analyze complex systems across different domains and scales, considering features of sustainability problems such as cascading effects, inertia, feedback loops.

- Anticipatory competences is about thinking about the future. It is the ability to analyze, evaluate, and craft pictures of the future related to sustainability problems and solution options.

- Normative competence is about assessing, considering others' values and needs, and taking a stance. It is the ability to map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets, as well as evaluate sustainability.

- Strategic competence is about getting things done. It is the ability to design and implement interventions, transitions, and transformative governance strategies towards sustainability.

- Interpersonal competence is about working with people. It's the ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving.

14. Which key competencies in sustainability did this class help you develop?

- Systems Thinking
- Anticipatory
- Normative
- Strategic
- Interpersonal
15. Did this course help you develop interpersonal competence in sustainability? If yes, give specific examples of knowledge, skills, and attitudes related to interpersonal competence that you developed through this class.

16. Did this course help you develop strategic competence in sustainability? If yes, give specific examples of knowledge, skills, and attitudes relevant to strategic competence that you developed through this class.

17. Rank the following CLASS COMPONENTS in terms of their usefulness in helping you develop INTERPERSONAL COMPETENCE (1= most useful, 4= least useful).

- Lectures
- Class Activities
- Tools
- Readings

18. Rank the following CLASS COMPONENTS in terms of their usefulness in helping you develop STRATEGIC COMPETENCE (1= most useful, 4= least useful).

- Lectures
- Class Activities
- Tools
- Readings

19. Rank the following TOOLS in terms of their usefulness in helping you develop INTERPERSONAL COMPETENCE (1= most useful, 4= least useful).

- Code of Collaboration
- Meeting Agenda and Notes
- Work Plan
- Picking Your Methods Worksheet
- Tips for Teams Booklet
20. Rank the following TOOLS in terms of their usefulness in helping you develop STRATEGIC COMPETENCE (1= most useful, 4= least useful).

- Code of Collaboration
- Meeting Agenda and Notes
- Work Plan
- Picking Your Methods Worksheet
- Tips for Teams Booklet

21. The tools introduced to you in this class are used in projects in many academic and professional settings in many different fields. Do you think that they are particularly valuable for sustainability projects? If so, why? If not, why not?

22. Any comments, ideas, or suggestions regarding tools used to support teamwork and project management in sustainability classes?