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How not what: teaching sustainability as process

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Ever since the word “sustainability” entered public discourse, the concept has escaped definition. The United Nations has christened the years 2005–2014 “The UN Decade of Education for Sustainable Development” and has called upon universities “to make education for sustainability a central focus of higher education curricula, research, physical operations, student life, and outreach to local, regional, and global communities.” Nevertheless, the indeterminacy of sustainability as a concept has challenged those designing university sustainability efforts, in terms of both campus planning and curricula. Some instructors and campus sustainability planners have chosen to stabilize sustainability concepts into a technical and ethical “greenprint” based on some agreement concerning shared (or imposed) concepts and values. Yet others have realized that this is not a problem to be “solved” but instead presents an opportunity to advance and implement alternative approaches to teaching and learning “post-normal” or “Mode 2” science. This article describes a curricular design that attempts to maintain both canonical disciplinary learning about the techniques of sustainability and training in the reflexive skills necessary to explore sustainable change through post-normal learning processes, which we delineate as three “modes of knowing.” By training students to practice these ways of knowing sustainability, they come to understand the “how” of sustainable practice, process, and design, while allowing the “what” of sustainability to emerge from group interaction in a collaborative context.

KEYWORDS: education, learning, colleges and universities, design, environmental engineering, sustainability

The Challenge of Teaching Sustainability in the University Context

The United Nations declared 2005–2014 to be the Decade of Education for Sustainable Development, calling on universities to help create a more sustainable world (UNESCO, 2005). Yet, higher education may not be well prepared to fulfill this goal. Historically, the university has created knowledge with individual experts in siloed disciplines who research and transfer codified knowledge using didactic pedagogies (Jonassen, 1991; Sharp, 2002). Yet, many observers have argued that working toward a sustainable future requires educational models that go beyond teaching codified “what” facts to models that emphasize “how”: that train students in the transdisciplinary, collaborative ways of knowing-how that have been recently characterized as “new knowledge production” (Hessels & van Lente, 2008), “post-normal,” or “Mode 2” science (Functowitz & Ravetz, 1993; Gibbons et al. 1994; Wiek et al. 2011).

In this article, we describe the problems with defining sustainability as codified, stable “whats.” We then look at new characterizations of sustainable knowing and learning as a more collaborative, “dialogic” process (Gibbons et al. 1994). These new con-ceptionalizations of knowledge production separate out codified didactic knowledge—what we call here “know what”—from the more contextual, tacit, and relational knowledge production we emphasize here and refer to as “know how.” We then ask, can universities, as centers of codified, disciplinary knowledge, teach students how to practice this new way of knowing? Then, we use one example of an interactive learning activity we have designed to train students to be competent, reflexive producers of sustainable knowledge in collaborative group processes. Through our own collaborative process of designing this learning activity, we found that students practiced three post-normal “modes” of knowing. We describe each of these modes and show how the learning activity evolved to explicitly teach both disciplinary technical learning about sustainability along with these other three transdisciplinary, reflexive process-based “how” modes of knowing. Finally, we briefly show how we are developing ways to assess student acquisition of these process “how” knowledge competencies.

Our example comes from a learning activity we have designed and conducted as part of the University of California (UC) Santa Cruz Sustainable Engineering and Ecological Design (SEED) consortium, a
group experimenting with reflexive pedagogical designs and learner-centered curriculum to train students to work effectively within collaborative group processes (Bacon et al. 2011) to create positive sustainable change.

**Sustainability as What**

A focus on sustainable knowledge and practice as simply gathering and imparting to students the right codified information has led to confusion in the classroom. Sustainability knowledge continually slips out from under these codified, standardized, canonical definitions. This situation has led to a frustrating indeterminacy in which “[s]ustainability appears to be about ‘everything’ and ‘nothing’ all at once,” (Sherren, 2006) so that “[a]t times, the plurality of angles, concerns, and interests embodied in sustainability debates devolve into a confusing cacophony” (Brand & Karvonen, 2007). The slipperiness of sustainable knowledge means that those attempting to prepare students to make informed contributions are often puzzled “in stipulating what is core to educate in something so amorphous as sustainability” (Sherren, 2006) leaving universities to become caught up in the question (to paraphrase Dave Eggers (2006): “What is the What?” of sustainability.

Universities have so far emphasized answers to “what” questions, fulfilling the United Nations sustainability mandate by creating campus “greenprint” plans that lay out sustainability “best practices” (Heinz Family Foundation, 1995; Bulkeley, 2006), a set of advisable technology adoptions to make campuses more “ecoefficient” (Bartlett & Chase, 2004; El-Mogazi, 2005). In addition, campuses often combine these technological recommendations with new “sustainability learning” initiatives that include inculcating “values and motivations that bring about environmentally responsible behavior” (Hansmann, 2010). In other words, universities teach notions of what technologies are sustainable along with what norms and behaviors lead to “good,” sustainable lifestyles (Sherren, 2006). In these greenprint processes, a group of interested stakeholders on campus define sustainable technologies and behaviors and then hope that business decisions and instruction will follow suit. These processes of sustainable knowledge creation tend to be reductionist, that is, to reduce sustainability to a simple list of technologies and behaviors, both in terms of the sustainability plans for the campus itself and a set of codified facts and values that should be taught (Bulkeley, 2006). Pedagogy also tends to be didactic, relying primarily on the lecture-test “banking” model, an approach that treats students as passive recipients receiving codified information transmitted to them from “the sage on the stage” (Friere, 1970; Sharp, 2002; Gao et al. 2007). This “codify and convince” strategy of creating sustainable change is not confined to the classroom. It is evident in a broader range of campus sustainable planning operations. Organizations such as the Association for the Advancement of Sustainability in Higher Education (AASHE) standardize sustainability into a set of “best practices”—technologies and behaviors—and then certify an institution’s progress in meeting these standards through the “Sustainability Tracking Assessment and Rating System” at levels from bronze to platinum (AASHE, 2012).

**Sustainability as How**

In contrast to these “codify and convince” university planning and teaching initiatives, new approaches define this sustainable knowledge as “post-normal science” comprising “a multiplicity of knowledge as well as a multiplicity of forms of knowledge” (Brand & Karvonen, 2007) requiring new, multidisciplinary, “reflexive” research and pedagogies (Functowitz & Ravetz, 1993). These scholars describe sustainable knowledge production as “a vibrant arena that is bringing together scholarship and practice, global and local perspectives from north and south” (Clark & Dickson, 2003).

Weik et al. (2011) recognize that training students in the post-normal science of sustainability “does not imply that ‘regular’ competencies, such as critical thinking and basic communication skills, are not important for sustainability professions and academic programs (they are!).” However, they argue that there are several other key competencies “critically important for sustainability efforts” (Weik et al. 2011). To teach these post-normal key competencies requires “an alternative model of policy learning [that] points to processes of argumentative struggle between competing frames or discourses as a means through which new understandings of policy problems arise, and policy change takes place” (Bulkeley, 2006). Teaching the “how” of sustainability requires us to “replace pedagogical approaches based on (relatively ‘authoritarian’) transfers of information with more interactive and collaborative learning processes: citizen participation can start with the creation of a community of learners” (Simon, 2002). In addition, a growing body of research in the learning sciences has shown that courses that rely only on didactic pedagogic strategies are less successful in attracting, retaining, or preparing students for STEM
(science, technology, engineering, and mathematics) disciplines (Seymour, 2002; Smith et al. 2009). For these reasons and others, this article explores research on post-normal forms of knowledge and on socioconstructive pedagogies to teach noncodified or “reflexive” ways of knowing.

UC Santa Cruz’s SEED curricular design team has been experimenting with pedagogy that embraces the reflexive nature of sustainability as a field or a concept. Defining sustainability is not taken as a problem that needs to be “solved,” but an opportunity to raise new ways of thinking about the world. This approach recognizes sustainability as an intrinsically unstable concept, a dynamic idea that can never be pinned down to a particular technology, set of behaviors, or even worldview and set of values. Under this scenario, the challenge becomes to design a curriculum around an unfixed concept and engage students with multiple modes of knowing without creating an unfocused strategy, agenda, and pedagogy.

Faced with this challenge, SEED curriculum designers have to date focused on training students in understanding multiple frames, problem-based and transformational learning, critical thinking, and dialogic exchange in group learning (Wells, 1999; Thomas, 2009). These emphases shift the focus away from codified knowledge toward various processes—“modes”—used to create new understanding (Barad, 2007). Our approach follows sociocultural theories of learning and teaching that focus on alternative options for participation in “joint activity” (Lave, 1991; 1996; Lave & Wenger, 1991; Rogoff et al. 2003). These efforts reflect broader transformations in the conceptualization of knowledge and understanding toward an embrace of what Silvio Funkowitz & Jerome Ravetz (1993) characterize as “post-normal” knowledge, what Gibbons et al. (1994) call “Mode 2” forms of knowledge, and revive ideas about those kinds of knowledge that escape codification, or what Karl Polanyi called “tacit” knowledge (Nonaka & Takeuchi, 1995). We characterize all of these understandings as “know how” modes of knowing. According to this perspective, leaving the definition of sustainability open, interdisciplinary, and emergent enables a focus on the “how” of technical and social processes informing sustainable designs (Brand & Karvonen, 2007).

Curriculum design that enables the “what” of sustainability to continually emerge and be redefined through group interaction around intersubjective knowledge-production practices prepares students for the kind of experimental creativity, reflexivity, and collaboration that will be required to produce new sustainable ways of knowing and living. Gibbons et al. (1994) describe this kind of knowing as always in the making. It is experiential, discursive, processual, social, tacit, contextual, transdisciplinary, open to different worldviews, collaborative, practice-based, and informal (Martens, 2006; Brand & Karvonen, 2007; Luks & Siebenhüner, 2007). In this kind of “new knowledge production” (Hessels & van Lente, 2008), discursive processes are not seen as separate from scientific research but rather as integral to it. This leads to a more dynamic and decentralized view of knowledge-creation as emergent and historically “contextualized,” based in practices and distributed across agents and artifacts (Cole & Engeström, 1993; Gibbons et al. 1994; Shove & Ingram, 2008). Such a counterview is based on acceptance of coexisting multiple ontologies, in which codified knowledge exists with other marginalized knowledge processes that are contingent on context and exist only so far as they are “in use”—that is, applied through interpretation, experience, and practice.

Ways of Knowing How

The increasing acceptance of multiple ways of knowing does not lead automatically to new forms of pedagogy. To achieve collaborative learning, students need to work through their multiple and competing ways of knowing and commit to a process of collaboration despite tacit and/or explicit commitments to different frames/worldviews: ways of understanding and of acting in the world. To teach these skills we relied on the work of educational theorists John Dewey, Paulo Friere, and others working in the Dewey tradition, such as Jerome Bruner (1990). These education thinkers have attempted to create socioconstructivist pedagogies around active, experiential, service, and practice-based learning that require not only training across fields but also in the application of collaboration skills that can span disciplinary divides/boundaries. We ultimately categorized our pedagogy into four separate modes, including the didactic strategy of teaching normal science as “facts”—knowledge that is delivered from experts to non-experts—and three collaborative, post-normal modes of knowing (Table 1).

Know How 1: Subjective Knowing

Each person learns important information through personal experience, history, and their own social situatedness. Subjective knowledge is the embodied knowledge we carry within ourselves though our histories and connections. A number of scholars have been seeking recognition for this kind of “situated” (Haraway, 1988), “local” (Geertz, 1983), and “standpoint” (Collins, 2000) or “witness” knowledge (contextually based and “true” in particular places, with particular people in particular times and contingent to particular situations). Postcolonial and critical
race theories especially emphasize witness testimony based in particular histories, memories, identities, subjectivities, and embodied knowledges (Ahmed & Stacey, 2001). These are also the knowledges tied to a particular culture’s ecologies (Cronon, 1983) or agroecologies (Altieri, 1995).

Those who take the subjective-knowledge perspective see Kuhn’s (1962) notion of paradigm as restrictive. Different ways of knowing can coexist even if one form has dominance. Sustainable agriculture provides an excellent illustration of this point; because it depends on a more agroecological, and therefore place-based context, it tends to be more tacit and situated and therefore harder to teach. Industrial agriculture, on the other hand, is dominant not only because industrial economic interests heavily influence agricultural education but also because industrial agriculture knowledge is more codified and universalizable, a form of knowledge more open to didactic university pedagogies (Goodman et al. 2011).

**Know How 2: Discursive Knowing**

Discursive knowing is produced through social interaction and respectful deliberation among collaborators who work jointly to complete complex tasks that require coordinated action. As Tomasello and his colleagues have explained (Tomasello, 1999; Tomasello et al. 2005), coordinated action requires establishing a common purpose and a “joint focus of attention.” Since complex tasks require a division of labor, individual participants who come with different histories, worldviews, and frames of understanding must learn “intersubjectivity”: to communicate their individual subjective understandings through language (verbal and written), gesture, physical movement, facial expression, demonstrations, symbolic inscriptions, and so forth in ways that articulate and respect subjective framings, yet accomplish common goals.

Like personal subjective knowledge, discursive knowledge is often a combination of rational, tacit, and emotional knowledge. Rather than seeking universals, it involves how we, in society, cope with various predicaments, contradictions, and dilemmas that are intrinsically irresolvable, “wicked” problems (Rittel & Weber, 1973). Yet, despite this irresolubility, we must make decisions in order to act. Discursive knowing, however, is intersubjective rather than subjective because it is carried out in concert with others, either through face-to-face deliberation or through civil discourse in public arenas. The intersubjective knowledges that result from these social interactions are neither situated in any one subjective position/standpoint nor represent a singular universal truth. These knowledges are contingent on the unique constraints and affordances of the activity underway, including the material, social, and historical context of that activity and the specific tools and resources available. It does not exist in the head of any one person or in the cultural ideas of one group of people. Instead, this type of knowledge is produced through social interaction, group decision making, debate, and collaboration. Scholars refer to this knowledge as coproduced (Jasanoff, 2004) or networked (Callon & Law, 1995).

From the discursive (or intersubjective) perspective, sustainability science is a design collaboration between various actors involved in new ways of living in the world rather than the pursuit of a prescribed end goal such as a set of sustainability greenprints. For example, new ways of looking at the history of technological design have shown that bicycle design emerged not from experts’ ideas of what a bicycle should be, but from designers paying attention to the diverse visions and needs of various user groups (Pinch & Bijker, 1984). Additional evidence of the importance of discursive thinking can be found in literature on business management and innovation, which has paid increasing attention to the problem of collaborative teamwork incorporating users early on in the design process (Oudshoorn & Pinch, 2003). Researchers have shown the importance of studying situations in which people bring different disciplinary, codified knowledges together to innovate a particular technology or product (Nonaka & Takeuchi, 1995). Nonaka & Peltokorpi (2006), for example, look at how engineers involved in designing the batteries, brakes, and electrical systems of the Toyota Prius had very different disciplinary viewpoints about the automobile as a system, and yet learned to work together to create one car that emerged through collaboration rather than the fulfilling of a single vision. These engineers succeeded.
not by moving toward one worldview but by working through particular kinds of group processes that enabled them to synchronize their differences as they made decisions about the design of the product.

**Know How 3: Practice-based Knowing**

New theories of social behavior have stressed various kinds of practice-based “know how” (see, e.g., Hargreaves, 2011). In a related way, Cultural Historical Activity Theory (Cole, 1985; Cole & Engestrom, 1993), Communities of Practice Theory (Lave, 1991; 1996; Lave & Wenger, 1991) and Actor Network Theory (Latour, 2005) emphasize the interrelations that organize decentralized networks of activity, including physical and social actions, shifting the focus from individuals to a dynamic “supra-individual” unit of analysis (Cole, 1985). Work in strategic management also emphasizes processes of trial and error in innovation and competent “know how” practice (Von Hippel, 1994; Nonaka & Takeuchi, 1995). Science studies scholars look at scientific knowledge production as more than the creation of codified knowledge through experiment and hypothesis testing, but as a form of situated activity—or practice—that is distributed across the tools-in-use, users, and material and social context in the field of discovery (Latour, 1987; Rheinberger, 1997). These scholars show how particular combinations of all of these elements are intrinsic to any performance and not merely variables among others. From this perspective, what we know (and how we come to know it) is not separate or distinct from what we do, and furthermore the particular ways we set about doing things will shape and orient what we know and understand at any point in time (Shove & Ingram, 2008). Since what we do, and the ways we go about doing the things we do, are constantly changing as we encounter new situations with different people, different materials, different social norms, and so forth, we must also assume that our knowledge base is continually being modified and adapted with each new performance.

Hargreaves (2011) explains the advantages of using practice-based theories to understand and promote proenvironmental behavior and sustainable social change. Practice-based perspectives abandon deficit models that focus on particular behaviors as “maladaptive,” “irrational,” or “ungrounded” and shift attention to the tensions and interplay among social conventions (e.g., patterns of consumption), immediate needs (e.g., staying warm) and the attributes of the material world that constrain and/or afford different possible actions (e.g., opening a shade in a south-facing window vs. turning up the heat) (Shove & Ingram, 2008). And unlike theories that focus on individual decision making as constrained by various contextual and/or conceptual barriers that need to be identified and removed, practiced-based theories of knowing emphasize how it is only through robust and continuing engagement that individuals build a coherent understanding of the complex relations that define the world around them.

**SEED Lab Activities as Scaffolds for Reflexive Learning**

The SEED curriculum trains students in reflexive thinking through peer support and collaborative pedagogies, often using Internet applications and other computer-based information technologies. The curriculum includes didactic learning of codified knowledge through lectures and readings as well as collaborative, active, group- and problem-based interactive exercises—which we call “labs”—and service-learning components. A lab series generally covers such technical concepts as life-cycle analysis, carbon-footprint calculation, and sustainable supply-chain analysis and examines topics ranging from raw materials and technology used in solar photovoltaic systems, to biofuels such as ethanol, to the marketing of commodities as consumer goods.

Individual labs are used in several classes, including general lower-division engineering courses on renewable energy and sustainable design; an upper-division sociology course entitled “Sustainable Design as Social Change”; and a senior capstone course open to all majors called “Impact Designs: Engineering and Sustainability through Student Service” that supports interdisciplinary teams of undergraduates in completing community-based sustainable design projects. Readings focused on technical content are paired with readings on communication strategies, sociological analyses of technical change, business-management theories of innovation, and histories of design. Lectures, readings, and prologues to the labs introduce students to codified information on different topics in sustainability. For instance, students learn about the technical concept of life-cycle analysis in assigned readings, through lectures, and with a lab activity on ethanol formulated to teach the role of reflexive analysis in understanding various ways to design life-cycle studies.

Each lab in the series is structured around the notion of scaffolding (Wood et al. 1976), a concept in education theory that explains how individuals meet new challenges, appropriate new skills, and develop new understandings during interaction. Scaffolding has been broadly defined as the process by which a teacher or more knowledgeable peer provides assistance that enables learners to accomplish tasks or succeed in problem situations that would otherwise be too difficult to resolve on their own (Wood et al.
students and collaborating community partners, pragmatic and authentic problem-solving (Bringle & Hatcher, 2007). Service learning can provide a number of different service-learning component integrated into most SEED courses.² Service learning involves students working and reflecting on their participation in projects that meet identified community needs. In these activities, students benefit not only from the opportunity to apply course content to actual practice, but also from an enhanced sense of public engagement (Dewey, 1986; Butin, 2003; Bringle & Hatcher, 2007). Service learning can provide a practical and authentic problem-solving contexts and broaden the student’s learning community beyond the classroom. These projects can be a powerful way to build a sense of student investment, motivation, and ownership. Through the application of academic content to tangible situations, service learning can support student appropriation of challenging technical skills and the understanding of complex ideas (Kezar & Rhoads, 2001). However, without a shared understanding of project goals, service learning can also be distressingly unproductive, wasting the time and “spinning the wheels” of both students and collaborating community partners, leading to an unwillingness to partner. The labs are designed to function as practice sessions, to prepare undergraduates to participate fully in collaborations with community partners to solve real-world challenges. It is important that they first practice key skills in a controlled setting and then are supported through the process of translating these skills into the applied context.

Example: The Packaging Lab

To demonstrate how a collaborative, active-learning curriculum design can support multiple modes of knowing, we will describe the first activity in the SEED series of interactive activities. Commonly known as “The Packaging Lab,” this initiative was originally developed as an opening activity in 2009 for Sociology 115: Sustainable Design as Social Change, an upper-division seminar that included an emphasis on student-led service-learning projects. The activity has since undergone several revisions and has been adapted to at least four other courses. Altogether, the activity has now been completed by approximately 500 undergraduates. In each case, The Packaging Lab was one of the first instructional activities presented to students.

This activity requires students to rank a set of consumer packages provided by the instructor, then reflect on and discuss their initial ranking before providing a “group” ranking, and then revisit their initial individual ranking to decide if they want to add changes to an individual “reranking.” After viewing the selection of consumer packages, students are asked to rank the way they were packaged. In some of these classes, students are simply asked to rank packages from “best” to “worst.” In some other versions, students are asked to rank packages specifically in terms of their sustainability: from “most” to “least” sustainable. Students are also asked to state reasons for each ranking, and then to boil down each reason into criteria they used to make their ranking (e.g., plastics can be recycled, plastics recycling reduces dependencies on petroleum, vs. plastics have been shown to disrupt ocean ecology). Students next defend their criteria to a small group of their peers and finally are given the opportunity to rerank the items, integrating any new considerations resulting from the small-group discussions.

The sequencing of successive “steps” within the activity is designed to help students work gradually, adding layers to complicate a working definition of sustainability as applied to different exercises in the lab. The idea is that students will learn the criteria they considered important in the definition of sustainability and, by discovering that other students have different criteria, learn that sustainability is a discursive concept not open to a single definition. The activity concludes with an instructor-facilitated whole-class discussion and some questions, typically assigned as homework, to give students further opportunity for reflexive practice.

**Step 1: Subjective Knowing**

We assume that most students will come to the lab with some notion of sustainability, such as ideas about recycling or conservation of energy and resources. We also imagine that a few students with more sophisticated ideas will include criteria related to more comprehensive views of sustainability such as the “triple bottom line” (economy, environment, equity). We expect that students will also bring their own priorities to their decision criteria—including economic feasibility, convenience, efficiency, aesthetics, social justice, and, of course, ecology—representing their different backgrounds and training.

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2 The SEED Curriculum includes a number of different service courses that involve students in problem solving of sustainability issues in the Santa Cruz community, including both lower division and upper division SEED courses.
Accordingly, the first step in The Packaging Lab is designed to help students reveal and then think reflexively about their pre-existing frames of understanding (both tacit and explicit). Students begin by individually ranking the packaging of selected consumer goods from “best” to “worst” or in terms of their degree of “sustainability” (with these concepts left undefined in the lab) relative to the others. Students invariably ask us to define these terms but are consistently reminded that it is part of their job to do so. After ranking each commodity, students are instructed to provide a reason for the ranking assigned. From this set of reasons, students are asked to identify and articulate the more general criteria they use to define sustainability (such as aesthetics, economics, reusability, recyclability, dematerialization). Students are able to see how different criteria, including some based on tacit assumptions or framing understandings, lead to very different rankings. For example, some students ranked a metal tin as sustainable because it could be reused while others questioned the assumption that it would be reused and gave it a lower ranking.

Student subjective knowledge includes the assumptions, expectations, and even the emotional or visceral reactions that each individual accumulates over time through different lived experiences. The lab prompts each student to understand (and thereby be prepared to articulate in Step 2) her or his criteria for sustainability. Rather than imposing a singular definition, the first step in this lab is intended to help students realize their own working definitions of sustainability and to compare with others by asking them to make and articulate concrete choices, and then reveal and reflect on their criteria. The goal is not only to awaken and expose students’ subjective knowing but also to prepare students to gain reflexive awareness about their own frames of understanding. Reflexivity—understanding how one’s own ways of knowing are based on who one is and that collaboration requires that we respect others who see the world differently—takes practice. This step is designed to give students some initial experience along these lines.

**Step 2: Discursive Knowing**

This step is designed to help students learn more reflexive knowledge practices, by compelling them to engage with the multiple subjective frames that different participants bring to a problem. Reflexivity as a practice is greatly enhanced by interaction with others who have different ideas about the world, in this case as expressed through focused discussion of the different criteria students individually assign to their rankings to support their working definitions of sustainability. In Step 2 of The Packaging Lab, students work in small groups and therefore must come up with consensual rankings despite different individual criteria. In the process of deciding on a final group ranking to present and defend to the rest of the class, the individuals in each small group consider and deliberate over the different rationales and criteria offered by other team members to decide which criteria justify their collective ranking. It should be emphasized that, during this activity, students were not encouraged to strive for absolute consensus or to agree on a singular vision but to bring their different worlds together through deliberation. Step 2 therefore compels students to go beyond merely articulating explicit criteria and to build intersubjective understanding through debate and argumentation with group members, even as they also come to understand how others might have different frames.

These small-group discussions are therefore a process by which students, through their reflexive understandings of their own “situatedness,” learn to make emergent decisions with others through a group process that does not try to come up with one “ideal” definition. Students further understand sustainability as a discursive concept and expand their own comprehension by adding new transdisciplinary, transframe layers to their prior definitions of the term.

Yet, this kind of discursive knowledge building can lead to problems in multidisciplinary design teams as people talk past each other, confuse one another, and disbelieve each other because each participant has a different frame. Therefore, to support discursive modes of knowing, our pedagogical approach includes not only scaffolds for students to reflect individually upon a more expansive definition of sustainability but also scaffolds for them to articulate their individual perspectives and to listen carefully to others’ articulations. To promote receptive/reflexive exchanges and deliberation, professors instruct students to read sources and to use careful listening techniques taken from nonviolent communication, a process skill designed to help groups resolve conflicts through increasing abilities to listen to others, to articulate one’s own frame, and to look for the common interests behind what look like intransigent positions. This training helps students to learn collaborative practices that are an intrinsic part of interdisciplinary teamwork.

**Step 3: Codified Knowing**

For subjective and discursive modes of knowing to become productive they must be infused with technical, codified knowledge production and practice. Throughout the course, all four modes of knowing, including the codified information produced by specialists, were recognized as important learning processes. However, instead of didactic
methods of teaching knowledge from “the sage on the stage,” the lab prompted students to seek out this knowledge on their own through joint research. While it may seem incongruous to plan for gaining technical knowledge as a third step in this largely diagnostic and reflexive activity, we found that, typically, it was indeed at this very point in their learning process that students began to ask technical questions to ascertain whether or not particular packages in fact met their subjective criteria (“Is this plastic recyclable?,” “Is less packaging that is less recyclable really better than more but recyclable packaging?”). Realizing the importance of the technical questions they were beginning to ask, students were then self-motivated to do their own research to support their arguments for or against the features of particular packages as representing the more sustainable choice. In the earlier versions of this lab, we found students spontaneously turning to the Internet and library searches, beginning a kind of investigatory research despite the absence of this step as a required feature of the exercise. As it seemed to be an activity worth encouraging, we have now formally added this new step, with some scaffolding to help students hone and apply research skills in ways appropriate for training in key technical research competencies that enable them to take part in cogent sustainability planning and practice.

Step 4: Practice-based Knowing

Knowledge gained through practical action is fundamental to human understanding: we come to understand concepts by putting them to use in the world. Students participate in practice-based meaning-making from the start of the lab activity. The subjective knowledge they offer and technical information they query and gather becomes more meaningful because they are actually using it to do something—in this case to make decisions (i.e., establish a ranking) and later to defend those decisions to an audience of their peers.

Like the learning activity itself, our design of this lab was a collaborative experience, using student evaluations and our observations to better design the activity. As noted above, we added a technical research component to the exercise because we found that students were turning to this activity on their own. In a future version of this lab, we plan to add a new step that asks students to design a new object based on the criteria that they have been exploring, thereby putting to work the process skills they have just learned. This step will further train students to apply this process knowledge to plan and justify design components of their service-learning projects. Our expectation is that students will gain a deeper knowledge of the subjective and discursive criteria they are using to distinguish “sustainable” from “unsustainable” materials and/or practices to perform the practical work involved in completing their larger service-learning projects.

What We Learned from the Packaging Lab

We examined the results from students completing this lab in two courses, Sustainability and Social Change (Sociology 115)3 and Sustainability Engineering and Ecological Design (EE80s). In both courses, we found that the activity generally accomplished what it was designed to do, namely: 1) expose students to multiple frames of understanding when it comes to distinguishing unsustainable from sustainable practice, 2) thereby increasing the number and broadening the scope of the kinds of criteria that any one student might apply (or at least consider), and 3) challenge and engage students through problem-based dialogue to work effectively with people who hold different sustainability worldviews, in order to 4) present sustainability as a complex rather than reductive concept and one that is fundamentally discursive in nature.

We found that initially, it was common for students to rely on one or two reductive characteristics in their first attempt to justify a rank order. For example, in the version of the lab that asks students to rank packages “from best to worst,” multiple students used a simple binary heuristic: was the package recyclable or not? Other students remained narrowly focused on the recyclability of a package, but went a bit further to consider the amount of and types of materials used. However, working within small groups to agree on a collective group ranking in Step 2, students exposed each other to other possible decision criteria. For instance, one student, an environmental studies major, reported that when she joined her group, she was surprised to find that other students described “best” in terms of convenience and safety. Conversely, another student in a lab that asked students simply to rank packages from “best” to “worst” and who evaluated her packages by how easy they were to open noted that “I didn’t think of sustainability and most of the group had this option.” In the version of the lab in which we asked students specifically to rank packages according to their “sustainability” (rather than a more general idea of “best”), students also found themselves thinking more broadly about the meaning of this term after com-

3 Sociology 115 was carried out both at UC Santa Cruz and as a version of the academic program at the University of California Washington Center (with DuPuis as instructor). In both cases, the students were involved in service learning internships and represented many majors, including science, engineering, social science, and humanities.
completing the exercises. For example, one student initially focused on whether or not a spray bottle was recyclable and/or “reusable,” but after completing the group discussion and reranking exercises the same student introduced her own notion of a “waste to functionality ratio” to justify her ranking, arguing that the increased amount of material made the bottle more reusable.

Irrespective of the initial prompt (“rank packages from most to least sustainable” versus “rank packages from best to worst”), it was less common for students to integrate multiple types of decision criteria into their first set of rankings. The number of students showing that they integrated multiple characteristics into their reasoning increased after students discussed their individual rankings with a group of their peers and then completed the group and individual reranking phases of the activity.

In some versions of the UC Santa Cruz electrical engineering course (EE80s, Sustainable Engineering and Ecological Design), we also used the lab as a pre- and post-assessment to evaluate what students learned in the class. Students completed the entire lab on the first day of class and again at the end of the course on the final exam. In this case, the same students were asked to rank and justify their rankings for a different set of packages and each of them wrote multiple statements (“entries”) to justify the rank order of each packaged item. Table 2 compares our assessment of a sample (n = 59 students) of student entries on the first day of class to their entries on the final exam. Student entries were characterized as being low-level, mid-level or high-level responses depending on their overall complexity and scored accordingly. Unsophisticated responses showed awareness of only one or two reductive characteristics without including specifics or qualifying statements, or noting any contingencies. Sophisticated responses 1) were characterized by multiple types of considerations, 2) showed more specificity within a theme (e.g., “mineral extraction” vs. “manufacturing”), 3) included more qualifying statements (e.g., the idea that waste should be measured against functionality), 4) showed awareness of contingencies (e.g., an item is reusable but only if well-preserved by the consumer) and 5) did not treat the package as a unified whole but rather as a composite of different materials. As Table 1 indicates, we found that from pre-to post-instruction in the electrical engineering course the proportion of high-level responses increased dramatically while the proportions of low- and mid-level responses slightly decreased.

We also analyzed whether the net differences shown in Table 1 could be attributed to the gradual improvement of many students rather than the dramatic improvement of just a few and found the former to be the case. Specifically, we found that on the final exam, the number of students in our sample (n = 59) that included one or more high-level entries in their response increased by 21 as compared to their performance on the earlier individual ranking exercise. We also found that, while only three out of 59 students (5%) produced responses that included more than three high-level entries prior to instruction, 11 out of 59 (19%) included more than three high-level entries on the final exam. It is also encouraging that the number of students giving responses characterized by a majority of low-level entries (5 > entries) decreased by 15% from pre- to post-instruction. While these results are evidence of student learning in only one particular course, they reflect the kind of improvement different instructors reported seeing across all courses using this lab.

After completing the ranking exercises and in-class discussions, students answered a series of reflective questions to compile a post-lab report. The work on these lab reports served to further improve their learning about sustainability as a complex concept, and also allowed us to better assess whether students were engaging in the multiple modes of knowing described in Table 1. Indeed, in reflecting on the lab, many students noted the discursive nature of sustainability. For example, one student wrote:

Since there are so many different definitions of sustainability it makes it difficult for society to agree on one specific one. I think a sustainable society has to come from baby steps. I believe that more likely than not, similar priorities of sustainability exist and it’s at these overlaps that we need to promote change. If someone were to just generalize all of sustainability into one giant definition, people would most likely be upset at

| Table 2 Low-, mid-, and high-level student entries. |
|-----------------------------------------------|
| Total entries in sample | Low-level responses | Mid-level responses | High-level responses |
|--------------------------|---------------------|---------------------|---------------------|
| Preliminary individual ranking exercise | 633 | 54% | 37% | 8% |
| Final exam | 788 | 48% | 31% | 20% |

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the statement made. That’s why we need to find the common ground between the definitions and work from there.

Other students were able to comment on the subjectivity of their own position and how they learned reflexively through exchanges with others. One student explained that “through discussion and compromise, I learned about a product’s benefits/negative elements that allowed me to reflect and change my ranking.” Another student found that she shared many of the criteria with others in her group, “but recyclability weighed more in the group than it did for me individually.”

Taken together, these results show that after instruction students considered a broader range of criteria and did so with greater sophistication. We are aware, however, that the activity, as well as our scoring criteria for student performance, is more suited to capturing changes in the “breadth” of students’ thinking than in its depth or sophistication about any one topic. For that reason, it is important to mix an activity like this one with others that focus in more detail on the specific skills and knowledge tied to particular facets of the larger sustainability question.

For the SEED team, the development of the lab was itself an interactive and reflexive design process that required understanding the outcomes of successive changes. To solicit student feedback on the activity as a learning experience, we administered exit surveys, which also changed as the labs developed. When asked about their general experience with the SEED pedagogy, all of the students (n = 39) participating in one iteration of this lab indicated that they either agreed (47%) or strongly agreed (53%) with the following statement: “Through collaboration within my lab and design teams, I learned things I cannot learn in a lecture-based class.” When asked to rate the effectiveness of The Packaging Lab specifically for advancing their learning and skill development, 75% of these respondents rated their experience with this activity as “strong” (rating 4 or higher on a five-point scale). In a comment section, several students reported that this activity in particular helped them to “weigh both sides” of a problem, understand how different people might “think/see things,” and helpful for “putting problems in another perspective.”

However, fewer students saw the connection between their learning and their service-learning activities; only two of 39 students responding to our survey rated their experience with The Packaging Lab as “highly effective” (rating 3) in preparing them for their out-of-class responsibilities, while 38% of the students indicated that it was moderately helpful at best (rating 3 or less). Overall, students did not view the central idea that design can emerge from collaboration in groups with different criteria and different worldviews about sustainability as critical to the success of their action-research projects or internships. Those who did not grasp this point judged the activity as unnecessary but “fun.” With our addition of Step 3, the practice step where students design their own package, we hope to help students connect their learning in class to their service-learning activities.

Overall, we learned that reflexive learning requires substantial class time, although with less lecture time. When students are struggling to find effective ways to collaborate, the professor needs to have some way not to rush the process, to let things go. At other times, the instructor needs to know when to intervene to move things along so that students see the value of the class-time work. When students do productive classroom work, it is also important to devote class time to recognize what has been learned.

We also learned that evaluating the acquisition of uncodified, reflexive knowledge is difficult within standard codified assessment systems. Our multimodal pedagogy requires a different approach to understanding and evaluating student learning. In The Packaging Lab, no one rank order was considered correct. Indeed, we were less concerned with the actual rankings than with how students arrived at different conclusions based on their stated criteria. These challenges compound the difficulties of assessing reflexive, noncodified student learning. It is by definition challenging to codify process learning. Also, if students feel that they have learned something on their own, they do not necessarily credit the pedagogical scaffolding tool that got them there. In addition, in professional assessment (and in articles like this one) researchers must show that the tool (and the professor) has been effective. These difficulties make it tempting to move back to didactic mode, where the professor “gives” the information to the students and is therefore clearly the source of the information.

In other words, collaborative learning requires that the instructor take on a significantly different role in the course, one that is sometimes difficult when one is used to the traditional role of being the authority. In classrooms where the professor is coaching collaborative learning processes, he or she may appear superfluous. In institutions where instructor merit is based on ratings by students, collaborative learning processes put the instructor’s reputation at risk.

Making the world more sustainable presents a formidable challenge for the future. As this study has shown, the challenge is more than just designing the right campus greenprint. Universities that seek to
provide sustainability education must face up to the challenge of training students to become dynamic, reflexive, and collaborative in how they arrive at new understandings and how they participate in multimodal knowledge-production processes. As we have suggested above, this has strong implications for teaching practice as well as for the overall organization of learning within a university setting. These challenges will not be easily met. In order for a university to research and teach sustainability through an interdisciplinary, dispersed, multimodal learning pedagogy, curriculum designers will need to overcome a long and entrenched history of presenting knowledge as "what": as immutable information held by experts and segregated into siloed disciplinary tracts. Universities that succeed in supporting faculty to create and implement these new types of curricula will better prepare students for the sustainability challenges ahead. UC Santa Cruz’s SEED program designers will continue to design—and redesign—learning activities to meet this goal. New collaborative and reflexive pedagogies to train students in post-normal modes of knowing will hopefully not just impact learning about sustainability, but also transform the university into a learning institution that gives students the competencies to meet the broader challenges of an increasingly complex world.

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