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4DEE—What's Next? Designing Instruction and Assessing Student Learning

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Contributions

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The Ecological Society of America (ESA) has recently adopted the 4-Dimensional Ecology Education (4DEE) framework. The 4DEE framework takes a fresh and innovative approach toward the teaching of ecology. Developed over the past three years by a task force of ESA members that solicited input from a variety of groups, ESA's 4DEE framework includes four dimensions that educators should integrate when teaching ecology: Core Ecological Concepts (core ideas central to the discipline), Ecology Practices (ways scientists use their knowledge), Human–Environment Interactions (ways humans and nature impact each other), and Cross-cutting Themes (concepts like scale and evolution that connect ideas and phenomena across disciplines; more information about the framework *available online*).[1]

This new multi-dimensional approach places distinctive emphasis on human–environment interactions, natural history, fieldwork, and ways of doing science that include working with data. The prominence of cross-cutting themes like spatial/temporal scale and disturbance highlights the importance for students to learn and integrate big ideas in ecology. In addition, increasing emphasis on human dependency on the environment and ecosystem management will highlight the relevance of ecological knowledge to human welfare. The framework also enhances our ability to communicate ecology broadly and to develop educational policy and practices that address current global environmental problems, especially to the diverse audiences impacted.

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With this new approach and its endorsement by ESA, a tremendous amount of innovation will emerge from the community of ecology educators as they use, modify, and extend 4DEE in research and practice. Their creative and critical research-based work will explore how to actually do and assess multidimensional teaching at different scales (e.g. a single lesson, course, course sequence, degree program, certification program) and in different contexts (e.g., non-majors, majors). The use of the framework by faculty, hopefully, will allow students to better learn concepts and skills in ecology. With the emphasis on useful skills and ways of thinking, we envision that students will find practical support for pursuing a diversity of careers beyond those of traditional academic pathways.

A description of the 4DEE framework was presented during a webinar (24 January 2019) by members of the ESA task force. Importantly, the webinar featured two exemplary cases of how instructors are using the 4DEE framework in their undergraduate ecology courses. The descriptions of these lessons follow. Our intention is to provide our colleagues with ideas and inspiration to begin using the 4DEE in their own courses.

How the 4DEE framework guided a course-based undergraduate research experience (CURE) at the University of Nebraska

CUREs are curricular interventions that seek to engage students in authentic scientific research practices by asking and answering research questions on a particular subject within the context of class sessions instead of a laboratory or other traditional research experience framework (see Auchincloss et al. 2017 for further discussion on CUREs). The CURE for Amanda. Sorensen's course focused on the socio-ecological drivers of swift fox (*Vulpes velox*) decline in short- and mixed-grass prairie habitats of Western Nebraska. The CURE took place during a 15-week semester and met for four 3-hour sessions, with 8 weeks in between the second and third sessions for students to implement their independent research projects. Conceptual modeling (ecology practice dimension) underpinned the CURE, where students generated and refined their individual mental models as the course progressed to help them integrate and synthesize new information about the system. The class used Mental Modeler software (Gray et al. 2013) for the conceptual modeling to help students integrate across disciplines (Sorensen et al. 2016). Further, the modeling was supported by a conceptual representation framework (PMC-2E, see Jordan et al. 2014), to help the students generate explanatory models that could be used to test hypotheses about relationships between components within the system. In each class session, students were asked to refine their individual mental models by integrating new information presented during that class. During each modeling session, students were asked to test and reflect on their models. Students were prompted to explain the relationships they represented in their models, make a prediction on what would happen if they changed certain components in their model, and then use the "Scenario" function in Mental Modeler to test their prediction. Once they ran the scenario, students were asked to reflect on whether the output matched their prediction and the content they learned throughout the course. Then, students were asked to revise their models.

The human–environment interactions dimension tenet of the 4DEE framework was integrated with the core ecological concepts aspects through this conceptual modeling practice in two ways: reading primary research literature and analysis of human-dimensions data during their research. During the first two class sessions, students were introduced to the swift fox and the broader socio-ecological system through a lecture on community ecology, discussions with a wildlife biologist, and reading primary literature. Students read eight peer-reviewed papers (four on ecological factors and four on human-dimension factors) that illustrated the scope of direct and indirect drivers of swift fox population decline. The in-class discussion prompts focused on how scientists know what they know, the limitations of the findings in each paper, and how the findings could inform their individual models. Students then integrated the findings from all of the papers into their individual models. By doing this, students explicitly had to grapple with considering how social factors, like demand for corn and beef, connect with and impact the focal phenomenon, swift fox decline.

Next, students used their individual models to develop hypotheses and research plans. Between the second and third class, students implemented the data collection protocol (discussed further in Sorensen et al. 2018), collecting both ecological data (presence/absence of fauna, vegetation sampling, etc.) and human-dimensions data (human proximity, dominant crop in sampling area, etc.). During the third and fourth classes, students used the class-wide aggregated data set to test their individual hypotheses. Many of the student hypotheses revolved around the relationships between particular fauna and aspects of the human-dimensions data. In the fourth class, groups of three or four students worked together to develop a consensus model of the system representative of swift fox decline. During each of these class sessions, students were refining, testing, and justifying their individual models as they were exposed to new ecological and human-dimensions data. The conceptual modeling practice paired with the CURE design helped the students intentionally integrate the human–environment interactions with the other core tenets (ecological practices, ecology concepts, and cross-cutting themes) from the 4DEE framework.

How the 4DEE framework guided a lesson for non-majors in an introductory biology course at the University of South Florida (USF)

Dr. Luanna Prevost used the topic of bee diversity to focus on the "Human–Environment Interactions" dimension of the 4DEE framework in a large enrollment course with ~180 students per section. Bee conservation is a topic of interest to the public (Wilson et al. 2017) and was repeatedly selected as a preferred topic by students in the course. Overall, this non-majors course was redesigned to use a case-study approach so that students could integrate multiple concepts in the context of real-world challenges. The course meets in a large auditorium with fixed seating. Despite this constrained physical environment, students were encouraged to work in groups of two to four and engage in instructional activities throughout the semester.

The bee diversity case study focused on several learning objectives including identifying ecological interactions between organisms (core ecological concept), interpreting data to deduce these interactions (ecology practice), and interpreting food webs to determine energy flow with an ecosystem (practice and cross-cutting theme). Students achieved these objectives while identifying causes and impacts of bee diversity on society and the environment (human–environment interactions). Each activity was aligned with objectives that centered on at least two of the four dimensions. This design ensured that over the course of the module, all four dimensions were addressed in various combinations to ensure alignment between objectives and activities, and assessments for improved student learning (Wiggins and McTighe 1998, Momsen et al. 2010).

Activities involved the use of data from primary literature and other visual representations as the context in which students examined core ecological content and cross-cutting themes. The first activity of the case aligned with the ecology practices and human–environment interaction dimension objectives. Students were asked to determine the change in bee diversity in the United States and UK by interpreting maps showing current and past ranges and population sizes of bees (Whitehorn et al. 2012, Goulson et al. 2015). Students then hypothesized impacts of these changes on the environment and society. In a second activity, students were asked to interpret data on human influences such as pesticide use and monocultures on bee populations. A third activity incorporated all four dimensions and prompted students to make predictions on how food webs might be impacted by changes in bee populations due to human impacts. Each activity was completed in a small group and guided using worksheets with short-answer questions and opportunities to draw figures and diagrams.

We used a similar design for creating both homework and exam assessments. For homework, students were given different contexts and data from the literature to help apply ecological concepts and practices. For example, students were prompted to interpret data on pesticide impact on bee gut microbiome diversity and bee survival. These homework assignments also emphasized the human–environment interactions dimension that captured the attention of non-majors.

How do we know what students are learning in courses designed using the 4DEE framework?

The 4DEE framework is a guide for course and curriculum development and drives active learning by engaging students in ecological practices in classrooms or the field. Importantly, active learning focuses not only on how the instructor teaches but also on the ecology practices students use to learn the core ecological concepts, cross-cutting themes, and human–environmental interactions. Therein lies our challenge; how do we assess multi-dimensional teaching and learning in substantive ways that reveal students' understanding?

We begin by asking, what should students know and be able to do with the core ideas in an ecology course? We then create learning objectives that include scientific ecology practices and core ecological concepts and design assessments that ask students to use ecology practices to demonstrate their understanding of core concepts. Active learning instructional design provides all students the opportunity to use ecology practices to learn the core concepts. Many readers will recognize that we have just described backward design (Wiggins and McTighe 1998) for instruction. Key to backward design is aligning objectives, assessments, and instruction.

Now we provide ideas of how to design formative assessments to use during class meetings and summative assessments for exams, homework, projects, and research that demonstrate two-, three-, and/or four-dimensional learning. Note: Not every individual assessment item must include all four dimensions; most do not. We begin by creating a two-dimensional question that involves ecology practices and a core ecological concept. For example, the task we want students to do is make a model and then use the model to make a prediction (ecology practice) using content knowledge (core ecological concept). Our intent is to provide students the opportunity to demonstrate knowledge transfer from class to a new context/case by using modeling. We begin with a learning objective and assessment item.

Learning objective

Predict abiotic and biotic factors the influence primary productivity in various ecosystems.

Assessment item

Construct a model that shows the flow of carbon through an alpine tundra ecosystem and use the model to predict the consequences of increased summer temperatures on primary productivity.

This is a constructed response question that asks students to make a model (practice) about a core ecological concept (carbon cycle) in an ecosystem that they did not study in class. Students must apply and transfer their knowledge and use the skill (modeling) they practiced in class. Is this assessment aligned with the learning objective? This assessment could be designed in a multiple-choice format that may include several parts. Instructors at USF used a similar design for creating both homework and exam assessments. Students were given different contexts and data from the literature to demonstrate whether they transferred their knowledge to these similar but distinct tasks.

We acknowledge that writing valid and reliable, multi-dimensional assessments of student learning is not a simple task. Laverty et al. (2016) designed a tool to help instructors develop or modify their existing assessments so that they have the potential to elicit evidence of students engaging with three dimensions identified in *A Framework for K-12 Science Education* (NRC 2012). Although the 4DEE has an additional dimension, Human–Environment Interaction, the two frameworks complement each other. This assessment tool describes criteria to use to determine whether an assessment task has the potential to elicit evidence of students engaging with two or three dimensions. It is especially useful for writing both constructed response and selected response questions for which students are asked to use a science (ecology) practice to work with a core (ecological) concept.

We stop here to give you time to think about the next steps in your course and/or curriculum. Check out the 4DEE website[2] and do not hesitate to contact any of the authors of this paper or George Middendorf, Alan Berkowitz, Carmen Cid, Teresa Mourad, or Ken Klemow to discuss anything about the 4DEE framework and the instructional facets for using the framework.

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Notes

[1] http://www.esa.org/4DEE
[2] https://www.esa.org/4DEE/framework/

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