Engaging online students by activating ecological knowledge

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Abstract

The current COVID-19 pandemic has forced the global higher education community to rapidly adapt to partially- or fully-online course offerings. For field- or lab-based courses in ecological curricula, this presents unique challenges. Fortunately, a diverse set of active learning techniques exist, and these techniques translate well to online settings. However, limited guidance and resources exist for developing, implementing, and evaluating active learning assignments that fulfil specific objectives of ecology-focused courses. To address these informational gaps, we (1) identify broad learning objectives across a variety of ecology-focused courses, (2) provide examples, based on our collective online teaching experience, of active learning activities that are relevant to the identified ecological learning goals, and (3) provide guidelines for successful implementation of active learning assignments in online courses. Using The Wildlife Society's list of online higher education ecology-focused courses as a guide, we obtained syllabi from 45 ecology-focused courses, comprising a total of 321 course-specific learning objectives. We classified all course-specific learning objectives into at least one of five categories: (1) Identification, (2) Application of Concepts/Hypotheses/Theories, (3) Management of Natural Resources, (4) Development of Professional Skills, or (5) Evaluation of Concepts/Practices. We then provided two examples of active learning activities for each of the five categories, along with guidance on their implementation in online settings. We suggest that, when based on sound pedagogy, active learning techniques can enhance the online student's experience by activating ecological knowledge; moreover, active learning techniques should also be incorporated into in-person offerings once the current COVID-19 crisis has abated.

1. Introduction

The current COVID-19 pandemic has impacted most aspects of daily life, including but not limited to educational instruction. Because of state and federal quarantine orders, colleges and universities around the world have been relegated to providing virtual instruction rather than face-to-face education. Traditional face-to-face pedagogical approaches (e.g., lecture-based approach) are likely ineffective in fully engaging students in an online setting (Garrison, 2003; Slavich and Zimbardo, 2012). Thus, to deliver content effectively, instructors must adapt their approaches in accordance with research-based methods deemed successful for online instruction (Schrum et al., 2005; Crawford-Ferre and Wiest, 2012). Successful online instruction is best achieved when the instructor assumes the role of a facilitator, thereby guiding the students' learning experiences (Berge, 1995; Crawford-Ferre and Wiest, 2012; Slavich and Zimbardo, 2012; Vilppu et al., 2019). This strategy shifts the emphasis of online curriculum development from content-focused to learning-focused (Vilppu et al., 2019; Slavich and Zimbardo, 2012).

The purpose of learning-focused curriculum is to facilitate students' deep learning process by directing them in activities to help build their knowledge (Trigwell et al., 1999; Postareff and Lindblom-Ylänne, 2008). In the online environment, instructors should not merely transmit knowledge through passive learning activities such as reading, taking quizzes, and watching video lectures (Dixson, 2010; Vilppu et al., 2019). Rather, in addition to passive learning activities, effective online teaching must include the promotion of active, self-

regulated learning (Vermunt et al., 2017). Instructors should initiate and guide the students' deep learning processes so they are encouraged to actively construct their own understanding (Vilppu et al., 2019). Active learning is achieved when the students apply the information they have learned (Meyers and Jones, 1993; Slavich and Zimbardo, 2012).

Student engagement is a primary component of effective teaching. Active learning activities increase student engagement in online courses (Chickering and Ehrmann, 1996). Dixson (2010) determined from a survey of 186 higher education students that student engagement was successful when active learning assignments engaged the students with (1) the content, (2) the instructor, and (3) other students. Students' perceptions of their engagement levels were not dictated by the specific type of active learning activity. Rather, these perceptions were dictated by the students' sense of connection and increased when multiple opportunities for connection were provided (Dixson, 2010).

We identified four key elements for developing and effectively utilizing active learning activities from the literature (Figure 1). First, active learning activities should be centered on the learning objective (Koontz et al., 2006). Second, active learning activities should foster student engagement with content and higher-order cognitive skills (Meyers and Jones, 1993; Slavich and Zimbardo, 2012; Vermunt et al., 2017). Third, instructors must require students to complete the work because students put forth less effort when they are not held accountable for completing tasks (Janssens et al., 2002; Dixson, 2010). Finally, active learning activities must promote communication because students perceive activities as successful when the activities enhance communication among students and/or between students and the instructor (Dixson, 2010).

Ecology-focused courses are particularly challenging to deliver online with meaningful student engagement. The concepts and applications associated with these courses have traditionally been viewed as very "hands-on," typically requiring in-person instruction to effectively deliver information. Many ecology-focused courses are taught partly or entirely in the field and laboratory, where instructors provide information on basic concepts and also incorporate unscripted teaching moments. For these reasons, creating online ecology-focused courses or transitioning conventionally field-based ecology-focused courses to an online format can be difficult.

Regardless of course format, the primary role of the online instructor is to ensure the learning objectives are accomplished (Koontz et al., 2006). Therefore, active learning assignments should be developed based on the specific learning objectives for the course. From observational data and experience, ecology-focused courses seem to possess consistent themes (i.e., learning objectives). However, limited guidance and resources exist for developing, implementing, and evaluating active learning assignments that fulfil specific objectives of ecology-focused courses. To address these informational gaps, we (1) identify broad learning objectives across a variety of ecology-focused courses, (2) provide examples, based on our collective online teaching experience, of active learning activities that are relevant to the identified ecological learning goals, and (3) provide guidelines for successful implementation of active learning assignments in online courses.

2. Materials and Methods

We used The Wildlife Society's (TWS) list of online higher education ecology-focused courses as a guide for identifying and classifying our initial categories of learning objectives (The Wildlife Society, 2020). First, we reviewed the fields of study (e.g., categories of ecology-focused courses) for courses offered online that were listed on the TWS website. Specific fields of study listed included Biology, Botany, Communications, Ecology, Humanities, Physical Sciences, Policy, Administration and Law, Quantitative Sciences, Statistics, Sustainability, Wildlife and Natural Resource Management, Wildlife Biology, and Zoology. Collectively, we have taught courses in most of these fields of study; we only lack higher education instructional experience in courses dedicated to the Humanities field of study. After reviewing the fields of study, we used our collective experience to develop five learning objective categories that were broad enough to encompass course-specific learning objectives for the ecology-focused fields of study. Our initial learning objective categories were (1) Identification, (2) Application of Hypothesis/Theory, (3) Management of Natural Resources, (4) Development of Professional Skills, and (5) Evaluation/Application of Concepts.

Next, we gathered information directly through institutional websites and Google searches to verify our initial categorization of course-specific learning objectives for online courses that aligned with the list on the TWS website. We browsed course catalogs and departmental pages to locate syllabi for courses considered to align with fields similar to those listed on the TWS website. In cases where syllabi were not linked on institutional pages, we used key term Google searches to find available syllabi for courses. Key terms included the name of the institution paired with a field of study and the words "syllabus" and "online." We only obtained syllabi for courses currently offered at an institute; however, course syllabi were not restricted to the current academic year. Dates listed on procured syllabi ranged from 1999-2020. Additionally, some syllabi that we obtained were listed as "example syllabi," meaning they were from a previous year of the course, but the date was removed. We were not able to obtain syllabi from every institution listed on the TWS website due to limited accessibility. However, we did obtain syllabi from every field of study listed on TWS webpage. After reviewing the learning objectives for all of the syllabi, we deemed it necessary to modify our initial categories of learning objectives. We noted that (1) application of concepts, in addition to application of hypotheses and theories, appeared to be a consistent theme, and (2) evaluation alone, instead of evaluation/application combined, also appeared to be a consistent theme. Therefore, we modified our initial categories of learning objectives to better align with course-specific learning objectives. Our final five categories of learning objectives, based on similarities among the learning objectives listed throughout the course syllabi we reviewed, were (1) Identification, (2) Application of Concepts/Hypotheses/Theories, (3) Management of Natural Resources, (4) Development of Professional Skills, and (5) Evaluation of Concepts/Practices.

Finally, we categorized every course-specific learning objective listed on each syllabus into one of our five learning objective categories. Specifically, one person categorized all of the course-specific learning objectives based on keyword terms and synonyms of keyword terms we developed for each of our learning objective categories (Table 1). For example, keyword terms for our Identification learning objective category included (1) define, (2) describe, (3) identify, (4) learn, and (5) understand. Many course-specific learning objectives were broad and encompassed several keywords, thereby matching more than one of our categories. For example, where identification of a term was a learning outcome, the course-specific learning objective often also included the application of the term; therefore, this particular learning objective would align with our Identification category and our Application of Concepts/Hypotheses/Theories category. In cases like this one, the broadly-written course-specific learning objective was given credit for multiple categories (Table 1; Figure 2; Appendix A). It should be noted that the intent of this categorization scheme is not to rank the quality of courses or make an assertion that a course is lacking in certain aspects. The sole purpose of the exercise was to determine if our five learning objective categories indeed explained most course-specific learning objectives that were listed on syllabi across many ecology-focused courses.

3. Results

3.1. Learning objective categories

We obtained syllabi from 45 ecology-focused courses (Table 1; Appendix A). Each course syllabus had 3–18 learning objectives. We reviewed a total of 321 course-specific learning objectives. All course-specific learning objectives were classified into at least one of the following five categories: (1) Identification, (2) Application of Concepts/Hypotheses/Theories, (3) Management of Natural Resources, (4) Development of Professional Skills, or (5) Evaluation of Concepts/Practices.

Learning objectives categorized as Identification were included in 100% of courses (45 out of $n = 45$) and were mostly related to the identification of species (i.e., plants, animals), anatomy, types of data and graphical representations, terminology and definitions, laws, and ecological processes (Table 1; Figure 2; Appendix A). For example, a learning objective from a botany course that aligned with our Identification category was, "Define plant parts, major cell types, and organ types. Identify the basic processes important to plant growth and metabolism" (Michot; n.d.; Botany; American Public University System).

Learning objectives categorized as Application of Concepts/Hypotheses/Theories were included in 91% of identified courses (41 out of $n = 45$) and were mostly related to the application of knowledge to

ecological concepts/principles, natural selection, global distribution of biotic components (e.g., biomes, plant communities, animals), universal laws (e.g., thermodynamics, conservation of mass), the scientific method/research, policies/laws, biological hierarchy, and evolution (Table 1; Figure 2; Appendix A). For example, a learning objective from a forestry course that aligned with this category was, "Students should be able to critically analyze forestry-related problems and apply theoretical knowledge to obtain objective and justifiable solutions" (Grala; n.d.; Forest Resource Economics; Mississippi State University).

Learning objectives categorized as Management of Natural Resources were included in 71% of courses (32 out of $n = 45$) and were mostly related to biotic populations (e.g., plants, animals), abiotic components (e.g., water, nutrients), interdependency of abiotic and biotic components, conservation and policies that support conservation, and impacts of humans and other disturbance activities (Table 1; Figure 2; Appendix A). For example, a learning objective from an ecology course that aligned with this category was, "Explain how biotic and abiotic factors affect the abundance and distribution of plants and animals and understand how organisms adapt and evolve in response to changing environments; analyze the role of climate change in this context and discuss strategies for mitigating negative effects of climate change on renewable resources" (Johnson; 2014; Natural Resource Ecology; University of Florida).

Learning objectives categorized as Development of Professional Skills were included in 80% of courses (36 out of $n = 45$) and were mostly related to population/habitat management, applying research and statistical analyses to conservation and management, improving oral and written communication, applying laws and policies to conservation and management, and obtaining/comprehending scientific literature (Table 1; Figure 2; Appendix A). For example, a learning objective from a conservation biology course that aligned with this category was, "Students will learn how to find and use resources for answering questions or solving problems, and to develop skills in expressing oneself orally and/or in writing as well as acquiring skills in working with others as a member of a team" (Chynoweth; 2018; Conservation Biology; Utah State University).

Learning objectives categorized as Evaluation of Concepts/Practices were included in 64% of courses (29 out of $n = 45$) and were mostly related to the evaluation of policies/laws, abiotic and biotic processes/cycles, scientific method and inquiry, technological advances, impacts to conservation and management, written documents (e.g., laws, scientific literature), evolution, conservation, and human impacts to systems (Table 1; Figure 2; Appendix A). For example, a learning objective from an environmental policy and law course that aligned with this category was, "Evaluate success of current environmental statutes and rules" (Brekken; n.d.; Environmental Law; Oregon State University).

3.2. Example active learning activities for online courses

3.2.1. Identification

Example 1 – Defining characteristics and image boards (Appendix B.1) : The defining characteristics and image boards activity has been used in a Wildlife Plant Identification laboratory course at a split upper undergraduate/graduate level. This activity was developed as a pre-lab activity to aid students in identification of plants they would collect in the field. Students researched and developed a written description of plant parts (e.g., flower, leaves) that helped categorize the plant species into its group (i.e., taxonomic group such as family or genus, growth habit group such as graminioid or forb). Next, students conducted an online image search to find several images that aligned with the written description. Students applied this knowledge in the field to help them identify the correct type of plant to investigate the identity of using plant identification applications (e.g., iNaturalist). This activity could be modified for any course (e.g., introductory science courses, ornithology, botany) where the learning objective is to identify/group objects by using visually describable defining characteristics.

Example 2 – Diversity and taxonomic rankings (Appendix B.2) : The diversity and taxonomic rankings activity has been used in a Shark and Ray Biology field course at the upper undergraduate level. Course enrollment is typically 20 students. This activity was developed to highlight the wide diversity of sharks in the northern Gulf of Mexico while providing students with practice using a dichotomous key. First, students were presented with a Google Slides file that contained instructions and photos of preserved shark and ray

specimens. Then, students were given two hours to identify 34 specimens to a predetermined taxonomic ranking: order, family, or species. During the two-hour period, the professor answered clarifying questions about dichotomous key terminology or difficult-to-identify specimens using the chat function in Zoom. Finally, at the end of the two-hour period, correct answers were shared and discussed with the class. This activity could be modified for any course (e.g., vertebrate zoology or other taxon-specific courses) where the objective is to introduce students to diverse new taxa while familiarizing them with the intricacies of a dichotomous key.

3.2.2. Application of Concepts/Hypotheses/Theories

Example 1 – Biological hierarchy (Appendix B.3): The biological hierarchy activity has been used in a biology course at the introductory undergraduate level. This activity was developed as a lecture summary activity to aid students in applying the concepts and terminology associated with the hierarchy of biological organization (e.g., biosphere, ecosystems, communities, and so forth). Students applied knowledge by developing their own terminology definitions and study aids. Next, students applied definition of hierarchy by developing a hierarchical relationship of "everyday" objects (e.g., balls, writing utensils). Finally, students applied definitions of terms to classify levels within the biological hierarchy through critical thinking applications and drawing activities. This activity could be modified for any course (i.e., introductory science courses, botany, ecology) where the learning objective is to apply knowledge of a hierarchical classification system.

Example 2 – Coastal restoration plan (Appendix B.4) : The coastal restoration plan activity has been used in an applied Coastal Restoration course at a split upper undergraduate/graduate level. This two-part activity (1) was developed to help students critically think through the full process for restoration project development and immediately apply knowledge gained by creating a tangible product and (2) allowed for self-assessment of knowledge gained throughout the course by having students revise the product developed on day one into a final product turned in at the end of the course. Immediately after reviewing the syllabus on the first day of the course, students are given instructions to draft a short (< 5 pages including figures and tables) restoration plan on a topic/habitat of their choice that includes the typical components of most project plans, including: rationale/need, scope of work, anticipated benefits (outputs and outcomes), permitting considerations, monitoring, and budget. This is a Maymester course that meets all day for three consecutive weeks; students are required to turn this first activity in by the end of the first day (11:59pm local time), so they have approximately 14 hours to complete the assignment. The instructor is available to answer questions until 5pm, but only from the perspective of a potential funder, permitting agency, or stakeholder. This assignment isn't graded; rather, students receive full credit for 100% completion of the assignment. On the second day of the course, students are informed that they are expected to continue developing this plan over the duration of the course, present their plan to the class, incorporate feedback, and submit the plan for a final grade. The maximum length of the plan remains the same maximum of 5 pages. For the presentation component, students are evaluated on their effectiveness at delivering their presentation and their ability to answer questions. Their final plans are evaluated similarly to a grant application; specifically, for completeness (i.e., are all required components present?), justification (i.e., is the need for the project justified and explained?), realism (i.e., are the goals, scope of work, anticipated outputs and outcomes, and associated budget realistic?), and the overall quality of the writing. This activity could be modified for any course where a learning objective is to apply knowledge for the conservation and/or restoration of natural resources (e.g., wildlife management, fisheries management, natural resource management, conservation, etc.). The timeline associated with this activity could be adjusted to fit realistic expectations for courses with different meeting schedules.

3.2.3. Management of Natural Resources

Example 1 – Restoring native prairie plant community (Appendix B.5): The restoring native prairie plant community activity has been used in a Wildlife Plant Identification lecture course at a split upper undergraduate/graduate level. This activity was developed as a lecture summary activity to provide students with skills to evaluate the effectiveness of a real seed mixture used for restoring a native prairie plant community as wildlife habitat. Students were given the common names of plant species as listed on an

actual seed mix packet that was used to restore native prairie plant community in the Southeastern United States. Next, students were instructed to research background information (e.g., growth duration, native range, growing conditions) about, and wildlife use of, each plant species. Finally, students were asked to evaluate the effectiveness of this seed mixture and support their assessment with facts gathered from their research. This activity could be modified for any course (i.e., ecology, wildlife management, natural resource management) where the learning objective is to evaluate a tool used to restore a native ecosystem.

Example 2 – Google Earth Mississippi Estuaries Journey (Appendix B.6) : The Google Earth Mississippi Estuaries Journey activity has been used in high school AP Environmental Science and Honors Marine Biology classes as well as in informal education through a youth version of Mississippi's Master Naturalist Program called "Student Naturalist." It was inspired by a lesson titled "A Trip Down the Alabama River" in the Estuaries 101 curriculum from the National Estuarine Research Reserve System and the National Oceanic and Atmospheric Administration. In this activity, students use their knowledge of estuarine geography and natural and anthropogenic influences (e.g., nutrient runoff, dredging, development, etc.) on wetlands and coastal waterways that they have learned from previous lessons. They apply this information to answer questions regarding the potential impacts (e.g., eutrophication, coastal erosion, habitat degradation, hydrology changes, etc.) on Mississippi's waterways that would be associated with such influences and make suggestions for mitigation methods. The activity begins with students entering GPS coordinates into the Google Earth program; these initial coordinates "virtually" place them upriver in the Pascagoula River. They are then instructed to move in predetermined directions throughout waterways in the region, stopping at specific areas to try to determine what activities (e.g., golf courses, mining, refineries, roadways) they might see that are impacting that area as well as adjacent habitat. Lastly, the students are asked to supply potential solutions for reducing the impacts. The concept of this activity can be adapted globally to any region, and the questions can be modified to suit a multitude of environmental, geographic, and anthropologic conditions.

3.2.4. Development of Professional Skills

Example 1 – Initial and reply discussion board posts (Appendix B.7): The initial and reply discussion board posts activity was used in an Environmental Law course at the introductory undergraduate level. This activity was developed as a lecture summary activity to provide students with the opportunity to apply environmental laws to their professional life and practice communication skills. Students were provided web links to administrative code posted in a state town hall forum as required by public notice executive orders. Next, students were asked to write an initial discussion board post in which they formulated their opinion on three sections of the Administrative Code that were listed; two Administrative Code sections were chosen by the instructor and one was chosen by each student. Two days after the initial post was due, students were required to post a reply to any one classmate's initial post. For the reply post, students were asked to explain if they agreed or disagreed with their classmate and why. This activity could be modified for any course (i.e., introductory or upper undergraduate or graduate levels) where the learning objective is to develop professional opinions and practice communication skills.

Example 2 – Field notebook (Appendix B.8): The field notebook activity has been used at the introductory and upper undergraduate levels. Creating and maintaining a field notebook supports the development of multiple, broadly transferrable professional skills, including (1) accurate record keeping, (2) information management, (3) data collection, (4) observation and description, (5) connecting direct experience with broader theories, models, and hypotheses, (6) identifying questions, and (7) self-directed inquiry. Students are required to keep detailed field notebooks to record field observations and standardized data in real time using a model format based on exemplary styles (e.g., Remsen, 1977; Herman, 1986; Montgomerie, 2018). Students submit notes periodically during the course to provide the instructor with an opportunity to provide feedback, coaching for improvement, and prompts to direct future observations. The field notebook is used to assess learning and development as well as participation and engagement. Field notebooks are recognized as a high-impact learning activity and are commonly assigned in field-based courses within the natural sciences (Farnsworth et al., 2014). This activity could be modified for any course (e.g., geology, wildlife management, marine ecology) where the learning objective is to practice and develop professional

skills centered on observation and description, record-keeping, and contextualizing direct experience.

3.2.5. Evaluation of a Concept or Practice

Example 1 – Peer evaluation (Appendix B.9): The peer evaluation activity will be used in a new Aquatic Biodiversity Conservation course at the graduate level. This activity was developed as a lecture series summary and exam review activity to provide students with an opportunity to practice evaluation of peers' conservation education interpretative displays. Students were provided with resources, examples, and rubrics to develop their own interpretive display on a topic that will be selected by each student, but related to material from the lecture series on freshwater river ecosystems. Next, students will be given instructions regarding evaluation. Finally, students will use a faculty-developed grading rubric to evaluate classmates' interpretive displays on the merits of creativity, alignment of learning objectives with learning goal, scientific accuracy, and execution. This activity could be modified for any course (i.e., introductory, advanced undergraduate, graduate) where the learning objective is for students to develop original works and practice their evaluation skills.

Example 2 – Evaluate results of published literature (Appendix B.10) : The evaluate results of published literature activity has been used in a Wildlife Plant Identification lecture course at a split upper undergraduate/graduate level. This activity guides students through evaluating the results of published literature to determine if it supports a theory that has led to a common management practice. First, students are oriented to the learning objective for the activity in the assignment instructions: "Evaluate the results of the study to determine if it supports or does not support Aldo Leopold's theory of using livestock as a wildlife habitat management land; to set back the seral stage of succession by consuming grasses, thus increase abundance of forbs" (Leopold, 1933). Next, students are asked several key questions to guide them in pulling pertinent facts from the manuscript that provide supporting evidence for their evaluation. Finally, students are asked an open-ended evaluation question: "Did the researchers of this manuscript find a treatment effect that would support Aldo Leopold's theory of using cattle or livestock as a wildlife habitat management tool to set back the seral stage of succession?" This activity could be modified for any course (i.e., ecology, zoology, wildlife biology) where the learning objective is to evaluate the results of published literature to determine if it supports a concept or practice.

4. Discussion

The past half century has been marked by a gradual shift in higher education pedagogy from the transmittal model (i.e., "sage on the stage") to the transformational model (i.e., "guide on the side") (King, 1993; Slavich and Zimbardo, 2012). This transition was unexpectedly hastened by the current COVID-19 pandemic, which has forced the global higher education community to rapidly adapt to partially- or fully-online course offerings (Crawford et al., 2020). Fortunately, a diverse set of techniques already exist to facilitate transformational teaching, including active learning. Here, we further the knowledge from the literature by providing observations and suggestions from our collective use of active learning activities in ecology-focused courses.

First, online active learning activities should be explicitly focused on the learning objectives and, as such, should be relatively short. For example, we recommend that (1) fill-in-the-blank activities should be no more than 2-3 pages in length, (2) activities regarding a reading assignment should contain a maximum of 10 questions, and (3) discussion or forum activities should comprise 2-3 main questions. By restricting the length of active learning activities, online instructors are compelled to focus specifically on the primary learning goals for the course. As an added benefit, a small number of brief, focused activities provides students with a greater proportion of time to self-learn the material (i.e., at a comfortable pace and using individualized techniques) and develop their own interpretations (Vilppu et al., 2019).

Second, mandatory submission for active learning assignments can aid online instructors in tracking student attendance. This is particularly important for institutes that rely on federal aid funds. According to the Federal Student Aid handbook, students are considered "in attendance" in an online course when they (1) submit assignments or exams, (2) post comments in an online discussion, or (3) participate in an interactive

tutorial (Office of Distance Education and eLearning, 2017; E-Campus Solutions Center, 2020). Importantly, mandatory submission of active learning activities does not necessitate evaluation of every assignment by the instructor. Self-evaluation by the students is considered to be a valuable learning tool; in fact, evaluation is classified as higher-order learning (Berge, 1995). We evaluated online and face-to-face active learning activities using the same strategy: we assigned participation points for fully completed activities and then allowed the students to self-correct their answers. For example, in an undergraduate Wildlife Plant Identification course, we assigned active learning activities for every weekly lecture; if a student earned 100% participation points for fully completing an activity, then the student was granted access to the answer key for the activity. Although self-evaluation lessens the required amount of involvement from the online instructor, we still recommend that the instructor provide feedback on every submission to increase student engagement through student-instructor communication (Dixson, 2010; Slavich and Zimbardo, 2012).

Third, we recommend incorporating active learning activities that allow students to guide their own unique instructional journeys. This strategy, known as student-centered learning, enables students to independently discover the resources available to them. Although student-driven resource exploration requires the online instructor to spend more time guiding students (Gabriel and Kaufield, 2008; Schrum et al., 2005), it increases student engagement by creating communication opportunities among students as well as between students and the instructor (Slavich and Zimbardo, 2012). Student-centered learning also promotes student choice by allowing students to apply course material to their own interests. This further heightens student engagement because each student has the opportunity to play an active part in shaping the course content (Slavich and Zimbardo, 2012).

Fourth, if the online instructor opts to use active learning activities that increase student engagement through student-to-student communication, then the instructor must facilitate that communication. Prior to the start of the activity, it is imperative that the online instructor clearly state his or her expectations for courtesy and professional language. The instructor should also designate precise deadlines for student communications. In our experience, most online students wait until the last possible moment (i.e., the deadline) to submit comments and hand in work, which may result in insufficient time to finish a final product. A series of deadlines throughout the activity allows students to complete tasks in a step-by-step manner and helps to provide sufficient time for completing the final product and achieving the final learning objective. Finally, if the online instructor is requiring group work or peer evaluation at any point then he or she should divide the students into groups and set guidelines for the students to follow, thereby fostering a positive virtual environment.

Ecology-focused courses, especially field- and laboratory-based courses, present a unique challenge for online delivery. In field and lab settings, students are granted ample time for discovery, problem-solving, and reflection, all while receiving concurrent encouragement and guidance from the instructor, who naturally acts as a facilitator. These in-person experiences can never be completely replicated in an online setting; however, when based on sound pedagogy, the suggestions and techniques presented above can enhance the online student's experience by *activating* ecological knowledge, and can even be incorporated into in-person offerings once the current COVID-19 crisis has abated.

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Tables and Table Legends

Table 1. Methodology for assigning learning objectives of ecology-focused courses into our five author-defined learning objective categories.

Learning objective category	**Keyword terms**
Identification	Define, describe, identify, learn, understand
Application of Concepts/ Hypotheses/ Theories	Apply, develop, formulate, predict, provide, suggest
Management of Natural Resources	Conservation, laws, management, natural resources, policy, popula
Development of Professional Skills	Career paths, case studies, communication, laboratory skills, mod
Evaluation of Concepts/ Practices	Analyze, argue, assess, critique, determine, effects, evaluate, revie

Figure Legends

Figure 1. Key components, based on current published literature, of a given active learning activity designed to meritoriously increase student engagement.

Figure 2. Examples of higher education ecology-focused courses and course-specific learning objectives that aligned with our five categories of learning objectives. We obtained these learning objectives from course syllabi procured from institutional pages and Google searches.

Data Accessibility Statement

All data, products, and examples associated with this publication are fully presented or linked within the text.

Competing Interests Statement

None declared.

Author Contributions

Stacy L. Hines: Conceptualization (lead); Investigation (lead); Writing – original draft (equal); Writing – reviewing & editing (equal), **Anthony J. Vedral:** Conceptualization (supporting); Investigation (supporting); Writing – original draft (equal); Writing – reviewing & editing (equal), **Amanda E. Jefferson:** Writing – original draft (equal); Writing – reviewing & editing (lead), **J. Marcus Drymon:** Conceptualization (supporting); Investigation (supporting); Writing – original draft (equal); Writing – reviewing & editing (equal); Funding acquisition (equal), **Mark S. Woodrey:**Conceptualization (supporting); Investigation (supporting); Writing – original draft (equal); Writing – reviewing & editing (equal); Funding acquisition (equal), **Sarah E. Mabey:** Conceptualization (supporting); Investigation (supporting); Writing – original draft (equal); Writing – reviewing & editing (equal), **Eric L. Sparks:** Conceptualization (supporting); Investigation (supporting); Writing – original draft (equal); Writing – reviewing & editing (equal); Funding acquisition (equal)

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