Learning and Teaching in College: An Ecological Perspective

By Chris Call

Learning about rangeland ecology and management (and related disciplines) in college settings can be enhanced if faculty members have a better understanding both of underlying educational concepts and associated learning processes, and how students develop intellectually during their college experience. To do this, we need a framework that combines knowledge and perspectives from the disciplines of cognitive psychology, adult education, and ecology. Even though not immediately apparent, psychological, educational, and ecological literatures are linked by analogies and a common, transferable language. If this language becomes more accessible across these disciplines, bridges can be built to enhance learning and teaching. I will have to stretch some analogies; i.e., concepts and processes that apply to individual plants and plant communities will be applied to individual students and classroom communities, and strategies for improving rangeland weed management will be compared to strategies for improving student learning. My focus is on undergraduate education, and the need for educators to shift from a teacher-centered approach to a learner-centered approach.

Information Processing: How Plants and Humans Learn

It might seem strange, but plants and humans share several commonalities in how they process information and learn.¹ Consider the numerous challenges rangeland plants face as they attempt to acquire, transform, store, retrieve, and use resources to function in diverse, and often stressful, environments. Individual plants respond to heterogeneous soils, competition, herbivory, fire, variable climatic conditions, and human activities by altering their growth and development. The costs and benefits of any change in growth and development require assessment on the part of the plant. The plant gathers information about its surroundings, combines this with information about its internal state, and makes decisions to allocate limited resources among competing tissues to optimize its fitness. Environmental signals (gravity, light, humidity, CO₂, volatile chemicals, soil structure, mineral and water availability, and many others) are distinguished by specific receptors in leaves, stems, roots, and reproductive organs. Currently acquired information is integrated with stored in-

formation to generate adaptive responses to changing conditions. As plants adapt and grow, they modify their own environment and the characteristics of future perceived signals; i.e., there is a feedback loop.

A classic example of rangeland plants changing their growth and development in response to herbivory involves crested wheatgrass (*Agropyron desertorum*), a grazing-tolerant bunchgrass introduced to the western United States from Eurasia, and bluebunch wheatgrass (*Elymus spicatus*), a grazing-sensitive bunchgrass native to North America.² Following severe defoliation at the same site in northern Utah, crested wheatgrass plants rapidly re-established a canopy with three to five times the photosynthetic surface area of bluebunch wheatgrass plants. Compared to bluebunch wheatgrass, crested wheatgrass plants had a greater number of quickly growing new tillers, more allocation of resources to the shoot system than the root system, and a lower investment of nitrogen and biomass per unit of photosynthetic tissues. Plants of both species were growing in the same sagebrush (*Artemisia tridentata*) matrix and had adequate moisture and equivalent carbohydrate pools for regrowth following defoliation. Their different responses illustrate how currently acquired information (severe defoliation) is integrated with stored information (historical exposure/lack of exposure to frequent, severe defoliation by large herbivores) to determine the probability of success.

In a somewhat similar manner, students acquire, transform, store, retrieve, and use information to construct knowledge. These processes are influenced by many factors operating in an educational setting, including: learner characteristics (learning style, beliefs, motivation); instructor characteristics (expertise, level of engagement, empathy); teaching methods (lecture, small group discussion, project-based); and the teaching environment (classroom, field/lab, online). The most widely used information-processing model in cognitive psychology recognizes three types or stages of memory involved in learning: sensory memory, short-term memory, and long-term memory (Fig. 1).^{3,4}

Sensory memory serves as a perceptive filter, receiving information (stimuli) from the environment (light, sound, touch, smell, taste) and perceiving what is important and what

Figure 1. Stage theory model of information processing depicting how memory is involved in learning. Modified from Gagné et al. (1993).⁴ Used with permission of Pearson Education, Inc.

isn't important to register and send to short-term memory for further processing.^{3,4} Stimuli are transformed (encoded) into electrochemical impulses that the brain can understand, and memory is created. Sensory memory is very temporary (less than 0.5 second for visual information and about 3 seconds for auditory information), so forgetting information is a common occurrence. Thus, it is critical for the instructor to help learners identify the most important points in a presentation, discussion, or reading assignment. Individuals are more likely to pay attention to information if it has an interesting feature that is personally relevant and if it activates a known pattern where items are placed in familiar contexts.

Short-term memory—what we are thinking about at any given moment in time—has an extremely limited capacity and poses a major constraint or bottleneck to the way information is processed.^{3,4} Depending on the individual, 3–7 units of information can be processed at any one time. This information decays within 10–20 seconds unless it is rehearsed, and then it might be available for use or manipulation for up to 20 minutes. To get information stored appropriately in long-term memory requires that it be rehearsed and encoded in a meaningful way. Instructors can promote rehearsing by presenting information in multiple contexts and/or encouraging elaboration, where students think about the meaning of new information and how it relates or connects to previously learned material. Encoding (the transforming, organizing, and transferring of information into memory) can be enhanced with various strategies. Information can be organized or “chunked,” where many related items are stored in one unit, reducing the amount of information that has to be remembered. Units can be effectively transferred into a memory framework by making the material and its structure evident to learners with the use of concept maps. Together, the instructor and students can visualize how schemata (hierarchical representations of knowledge) grow and change as new information is acquired (Fig.

2). New information can be readily added to existing, correctly structured schemata, or it might require the restructuring of deep-seated schemata, which are often based on contradictory assumptions and beliefs—this is hard to do.

As new information is stored in long-term memory, it is organized into different categories: declarative memory (that which can be talked about or verbalized, e.g., personal experiences, specific events, concepts, and learning/problem-solving strategies); procedural memory (learned skills that have become automated, e.g., driving a car); and imagery (visual representations of information).^{3,4} This stored information is largely outside an individual's awareness, but can be retrieved into short-term memory to be used when needed. The two main retrieval processes are recognition and recall. Recognition occurs when a current experience activates the stored record of a previous one, whereas recall is based on reconstruction of previously experienced information, either cued by a current stimulus or elicited without external prompting. Because recognition involves detecting only a few key features of an event, it has a much greater capacity for retrieval than recall, which entails reconstructing the complete episode. The information in long-term memory and short-term memory is then sent to a response generator, which organizes an action, such as solving a problem or driving a car. Instructors can enhance storage and retrieval processes by presenting information in multiple formats (written, verbal, and imagery) and chunking it in meaningful ways. For example, when new concepts are introduced via lecturing, they should be organized into chunks or subunits with no more than seven common items per chunk, and each chunk should take no longer than 15 minutes to present. Before moving to the next chunk, the instructor should pause and facilitate a summarizing or processing experience (e.g., small group discussion) about the information just presented. By doing this, and not moving

Figure 2. Hypothetical schema showing how knowledge might be structured for a subject area such as sagebrush. Due to space limitations, only four topics (taxonomy, ecology, management policy, and wildlife habitat) are included to illustrate the complex hierarchical structure.

through an entire 50-minute lecture in a continuous manner, students have more time to contemplate the material, organize it, and store it effectively for future retrieval.⁵

After completing a response or action, the mind observes the effect of its performance and prepares itself to repeat the process as appropriate.⁴ This feedback process, metacognition, allows individuals to think about their thinking and learning. Metacognition can be developed and enhanced in novice learners by asking students to analyze their thinking as they attempt to solve a problem or reflect on a new ecological concept and its application in familiar and novel rangeland settings. Instructors, as more advanced learners, can model how they think about their thinking when responding to similar situations.

Conceptualizing Change in Plant Communities, Students, and Teachers

There are many similarities between plant community development and the development of student intellect and teacher competency. Rangeland ecosystems are influenced by multiple forces that vary in time and space, resulting in complex vegetation changes that have major implications for evaluation and management. During the last 20+ years, the range profession has adopted state-and-transition models that account for a broad spectrum of vegetation change (i.e., continuous/revers-

ible vegetation dynamics, discontinuous/nonreversible vegetation dynamics, and multiple stable states and successional pathways) in response to fire regimes, climatic conditions, grazing pressure, soil erosion, invasive species, and management prescriptions.⁶ State-and-transition models describe the circumstances associated with vegetation changes on specific rangeland areas (ecological sites), help promote critical thinking about the processes driving vegetation change (energy capture, nutrient/water cycling), and enhance communication among scientists, managers, and special interest groups participating in management planning and assessment.⁷

As most readers know, state-and-transition models conceptualize vegetation on an ecological site as existing in a reference state and alternative states with transitions among them (Fig. 3).⁶⁻⁸ Each state includes one or more plant community phases, which are defined by dominant species and occur at particular points in time. Transitions among community phases, referred to as community pathways, can be caused by drought, heavy grazing pressure, and other factors, but are reversible by altering the intensity or direction of the factors (increased precipitation, reduced grazing pressure). States are distinguished from one another by relatively large differences in vegetation structure, ecosystem processes, and management requirements. The interaction between the vegetation and soil components

Figure 3. Conventional state-and-transition model for a rangeland ecosystem illustrating multiple stable states, community phases and pathways within states, reversible and irreversible transitions, and thresholds. Modified from Stringham et al. (2003).⁸ Used with permission of the Society for Range Management, Allen Press Publishing.

through energy flow, nutrient cycling, and hydrologic processes defines the resilience and resistance of a state; i.e., its stability. If natural events and/or management actions degrade one or more of these primary ecological processes beyond the point of self-repair (i.e., beyond the limits of resilience and resistance), a threshold is crossed, triggering a transition to an alternative state. Unlike community pathways, transitions between states are not reversible simply by altering the intensity or direction of the factors that produced the change. Instead, they require intensive, and often expensive, practices (removal of competitive species, seeding, soil amendments) to restore some semblance of the vegetation structure and ecosystem processes that existed in a previous state.

Many of the terms and concepts described above for plant community change (states, transitions, and thresholds) can be used to describe the intellectual development of students in college settings. This is most evident for undergraduate students in the Perry Scheme of Intellectual and Ethical Development, which is based on a series of open-ended interviews conducted yearly with cohorts of Harvard students during the 1950s and 1960s.⁹ Perry's approach has since been replicated with more diverse undergraduate student populations at other institutions, with similar outcomes. The Perry Scheme is a

model that describes how undergraduate students come to understand knowledge, and the ideas they hold about knowing, thinking, and reasoning. Students pass through a sequence of nine positions or phases of intellectual development that can be grouped into four broader categories or relatively stable stages/states (dualism, multiplicity, relativism, and commitment to relativism) with transitions between them (Fig. 4).⁹

Dualism is the most common stage for entering undergraduate students, where they see the world in two realms, i.e., right vs. wrong. Authorities know the right answers, and it is their role to teach them. Knowledge is viewed as received truth. Peers are not viewed as a source of knowledge. Confusion arises when authorities disagree. Learners are uneasy with independent thinking, offering opinions, and drawing conclusions.

In the multiplicity stage, learners acknowledge multiple points of view, but have difficulty evaluating them. Views are seen as opinions to which everyone has a right. Professors are no longer viewed as authorities with the right answers, and students are baffled by instructors' criticism of their work.

As students move into the relativism stage, they recognize that most issues and questions can be complex. Diverse opinions, values, and judgments can be analyzed and compared. Authorities are no longer resisted, but are valued for their

Figure 4. Perry scheme of intellectual development for undergraduate students depicting multiple stages, transitions, and pathways associated with resistance to learning (temporizing, escape, and retreat). Adapted from Perry (1970).⁹ Used with permission of John Wiley & Sons.

expertise. Students gain new insights into what it means to know and learn, and they recognize that knowledge is contextual and relativistic. Crossing the threshold into this stage is troublesome, and few students fully embrace relativism during their undergraduate years.

In the last stage, commitment in relativism, students explore affirmation of truths and responsibilities on their own, typically after college. Personal commitments in their career, relationships, or other areas of life, are made from a relativistic frame of reference. Individuals integrate relatively objective and rational procedures of academia with more experiential approaches to other aspects of their lives.

Just as with vegetation change, student intellectual development is not smooth. Rather than transitioning from one stage to the next in a timely and predictable manner, many students choose alternative pathways via temporizing, escape, and retreat (Fig. 4).⁹ With temporizing, a student delays in a stage for a year or more, exploring its implications or hesitating to take the next step, as if gathering forces. With escape, a student exploits the opportunity for detachment in the multiplicity stage and avoids personal responsibility by viewing his/her perspective as being as good as anyone else's. With retreat, a student becomes entrenched in the dualism stage, remaining uncomfortable with diversity and ambiguity. Many students resist learning new knowledge and skills and thinking about different perspectives for a variety of reasons, including: lack of ability or aptitude, loss of certainty/security, risk of failure, loss of motivation (i.e., the energy required for unlearning and relearning), and a mismatch between learning style and teaching method. In an ecological sense, students are responding to learning episodes as "disturbance events," where their resistance allows them to remain in a less demanding developmental stage. Resistance can be lessened and learning and growth can take place by providing a facilitating environment where com-

munication is open, trust between students and the teacher is high, learners can experiment, and teachers understand the dynamics of intellectual development.¹⁰

Students can be helped through the Perry Scheme by first determining their level of intellectual development and then gradually exposing them to challenges that constrain transitions to multiplicity and relativism.¹¹ For example, at the beginning of the term, have students write a short essay on "How I Learn Best and How I Know That." Use the essay responses to adapt presentations, select appropriate activities and assignments, and determine the level of support that will be needed to facilitate learning and growth. Activities such as small group work and free-guided discussion diminish the instructor's authoritative role, expose students to ambiguity, and reinforce the importance of multiple perspectives. Dualists can observe knowledgeable peers disagree on important issues. Multiplists begin to distinguish well-supported ideas from poorly-supported ones. Relativists model higher-level cognitive skills, but they also benefit by observing peers dealing with uncertainty and the difficulties involved in reaching decisions. You can challenge all students by exposing them to a set of sample exam questions with the same content at different levels of intellectual skill; i.e., knowledge (recall), comprehension, application, analysis, synthesis, and evaluation. Provide appropriate and inappropriate answers, and discuss differences in the nature of the questions and answers and how they exemplify increasing complexity in thinking about a concept or issue. With all presentations, activities, and assignments, dualists will require a high degree of structure to operate within comfortably; i.e., numerous concrete examples and multiple opportunities to practice the skills of complex thinking.

College faculty, regardless of gender, ethnicity, and institutional affiliation, typically go through a developmental sequence in their approach to teaching as they mature. A

Figure 5. Model for college/university teacher development depicting multiple stages, transitions, and pathways associated with resistance to change (temporizing and retreat). Adapted from Robertson (1999).¹² Used with permission of Springer Publishing Company.

comprehensive review of the perspectives of “professors-as-teachers” resulted in a developmental model comprised of three relatively stable stages/states (teacher-centeredness, learner-centeredness, and teacher/learner-centeredness) with transitions between them (Fig. 5).¹²

Most new faculty enter their college careers in the teacher-centeredness stage, where the teacher’s responsibility is to know the content well and present it clearly, usually by lecturing. They generally teach based on how they were taught, without questioning these received models of teaching. Little attention is given to the students’ experience, and if it is, teachers project their own experience as learners onto students. Faculty members also focus on contexts that are pertinent to them, such as those related to tenure and promotion (i.e., research obligations).

For faculty who progress into the learner-centeredness stage, there is still an interest in content mastery, but the major focus is on the instructional process, particularly from the learner’s point of view. Received models of teaching (those emphasizing information transfer) are questioned, and teachers experiment with more learner-centered approaches (collaborative learning, problem-based learning). There is continued concern about professional advancement, but this is diminished by new concern with the contexts that relate to the characteristics of learners (learning styles, relevant past experiences) and to facilitating their learning. However, this concentration on the learning process is incomplete because the focus is on the learners and not on the teacher and the learners as full participants in the teaching/learning enterprise.

In the teacher/learner-centeredness stage, teaching strategies focus on facilitating the students’ learning processes, but with recognition of the ways in which the teachers’ experiences as learning facilitators and the students’ experiences as learners interact with each other and with course content. The teacher has developed an ecological perspective, where he/she

is thinking systematically about the relationships among the components in the teaching/learning enterprise.

Transitioning across thresholds between the stages of teacher development (i.e., responding to “disturbance events” similar to those encountered in student intellectual development) can often be threatening, leading many faculty to retreat to an earlier stage and remain there for an extended period of time (temporizing), or even an entire career (Fig. 5).¹² Resistance to embracing learner-centered and teacher/learner-centered approaches can occur for a variety of reasons, including: commitment to traditional instruction, fear of losing content and rigor, fear of losing control, fear of failure, and time investment in relation to rewards for teaching and research.¹⁰ Teachers can overcome resistance and build a stable, new teaching perspective by engaging in critical reflection, where they identify and examine the assumptions that influence how they teach.¹³ This involves viewing their teaching through several lenses: autobiographical experiences as learners and teachers, students’ and colleagues’ perceptions of their actions, and reading literature inside and outside their discipline to examine what they do within alternative theoretical frameworks (as I am trying to do in this article). Faculty can also seek support from like-minded colleagues who are open to learning about and using learner-centered and teaching/learner-centered approaches.¹⁰ Lastly, faculty can gain valuable information about learning processes and teaching strategies at education conferences and teacher development workshops; however, infrequent attendance at these events might not have a lasting effect if the information isn’t integrated with critical reflection and interactions with colleagues.

Management Applications

A better understanding of the ecological processes and environmental conditions influencing vegetation dynamics can im-

Figure 6. Use of successional management to align treatments that address the causes of vegetation change and promote a shift from a cheatgrass-dominated community to a desirable perennial grass community. Modified from Sheley et al. (1996).¹⁵ Used with permission of Weed Science Society of America, Allen Press Publishing.

prove the management of rangeland resources. Likewise, a better understanding of the learning processes and social factors influencing student and teacher development can improve the “management” of college instruction. Effective management, regardless of discipline, is typically guided by a decision-making framework, which integrates these processes and factors with thoughtful objectives, underlying principles, appropriate methods, and thorough assessment in a systematic manner.

This type of framework is used for developing ecologically-based invasive plant management (EBIPM) strategies on rangelands.¹⁴ A key component of the EBIPM framework is successional management. If land managers understand the underlying causes of succession (i.e., site availability, species availability, and species performance), and how they are influenced by various ecological processes, appropriate manipulation treatments can be aligned for effective weed management. An earlier version of the successional weed management model will be used to illustrate this alignment of treatments to address the causes of succession in a complimentary manner and promote a shift from a cheatgrass (*Bromus tectorum*)–dominated community to a more desirable perennial grass community (Fig. 6).¹⁵ Of the several manipulation treatments available, prescribed fire in early fall is used to reduce the litter layer and decrease the availability of safe sites for cheatgrass germination/establishment (site availability), pre-emergence herbicide (imazapic) applied soon after the fire is used to kill/injure fall-emerging cheatgrass seedlings and reduce competition (species performance), and seeding in late fall is used to increase the number of propagules of desirable perennial grasses for germination/establishment the following spring (species availability). Adaptive management, another key component of the EBIPM framework, allows managers to gain greater knowledge of their

rangeland system by testing treatment alternatives during the management process; i.e., to learn by doing.¹⁴

A similar framework can be used to “manage” college learning and teaching. We can align curriculum design, instructional methods, and assessment techniques to promote a shift from dependent and surface learning to more self-directed and deep learning, i.e., a shift from teacher-centeredness to learner-centeredness (Fig. 7).^{10,16} When designing a curriculum, clear objectives specify the level of understanding expected (outcomes), the key disciplinary concepts and skills to be learned, and the appropriate structuring of content within and among courses—keeping in mind how learners develop intellectually during their college experience. As with many natural resource disciplines, the range curriculum must meet professional accreditation (Society for Range Management) and federal agency hiring (Office of Personnel Management) standards, which can impact these design elements. Instructional methods should focus less on transmitting information (lecturing) and more on constructing knowledge through hands-on experiences (field and lab) and individual and group activities (case study problems, discussion groups, relevant projects). Electronic (online) learning and associated technologies (GIS, simulation models, Gigapan images) can be used effectively for constructing knowledge, especially when place-bound students can participate in a 1–2 week field experience (hybrid intensive course). Assessment should involve more than quantifying student performance on exams and assignments. Several qualitative techniques indicate whether learning has been successful, and they take little time to implement: constructing concept maps and analyzing sample questions and answers for exams (both described earlier), classroom assessment techniques or CATs (e.g., ask students, “What was the most confusing idea [muddiest point] in today’s presentation?”),¹⁷ and the critical

	Curriculum Design	Instructional Methods	Assessment Techniques	
Dependent learning	Objectives	Lecture	Exams	Self-directed learning
	Outcomes	Field / lab	Assignments	
	Concepts & skills	Case study problems	Concept mapping	
Surface learning	Content structure	Discussion groups	Questions for exams	Deep learning
Teacher-centered approach	Learner developmental level	Project-based	CATs	
	E-learning & technology	CIQ		Learner-centered approach
	Accreditation & hiring standards	Hybrid intensive	Portfolios	

Figure 7. A “learning/teaching management model” that aligns curriculum design elements, instructional methods and assessment techniques to promote a shift in teaching approach and enhance student learning. Adapted from Biggs (1999).¹⁶ Used with permission of Taylor & Francis Group.

incident questionnaire or CIQ (comprised of five questions to find out how students are experiencing their learning and your teaching).¹³ A more comprehensive assessment tool is the student portfolio, which monitors student progress over a course or an entire core curriculum. As with EBIPM, adaptive management is a key component of a learning/teaching management framework, where successes and failures are examined and appropriate changes are made in teaching to facilitate more effective learning.

Conclusion

If we, as range educators, recognize the analogies and common language linking the disciplines of ecology, cognitive psychology, and adult education, we can gain a better understanding of learning/teaching concepts and processes, and their application at the college level. Emphasis should be placed on student intellectual development and faculty teaching development, both of which share many similarities with plant community development. Frameworks, much like those used in range management decision-making, can then be developed to align curriculum design, instructional methods, and assessment techniques, and enhance student learning.

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