Undergraduate Research in Agriculture: Constructivism and the Scholarship of Discovery

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Experiential learning is a hallmark of undergraduate education programs in the agricultural sciences, and is aligned with constructivist learning theory. This interpretivist qualitative study used historical research methodology to analyze the epistemological underpinnings of constructivism and explore the construct's relationship to undergraduate research, a particular experiential learning context which extends a student's knowledge to scholarly application through discovery–based problem solving. Two pedagogical principles of constructivist learning theory emerged: that learning should be authentic, active and student–centered, and that it must also be facilitated through social negotiation. Both factors are inherent in the learning process when faculty mentors scaffold the creation of new knowledge via undergraduate research. Agricultural educators can take advantage of parallels between constructivism and the scholarship of discovery to enhance self–regulated learning of students and integrate institutional research and teaching missions.

Keywords: constructivism, historical research, experiential learning

Introduction

There is growing urgency for academic reform among agricultural colleges within higher education (Fields, Hoiberg, & Othman, 2003; National Research Council, 2009; Osborne, 2007). The escalating rate of global change has created mounting pressure to solve complex societal challenges linked to the world's food and energy supplies. These solutions require broad, system–wide approaches, multidisciplinary strategies and collaborative efforts of discovery and innovation. To meet this need, today's students in the agricultural sciences must be educated as adaptive and resourceful lifelong learners, able to deal readily with dynamic, complex problems facing 21st century society. Essential is the development of cross–cutting curricula which promote creative and critical thinking, discovery–based problem solving, leadership and communication skills, all in a manner that challenges students to make connections across disciplines with strong grounding in the traditional STEM disciplines of science, technology, engineering and mathematics.

For decades, experiential learning models have been a hallmark of agricultural science programs (Andreasen, 2004). Mastering concepts and skills 'in context' develops higher–order thinking and transferrable skills necessary to prepare the workforce of the next generation (NRC, 2009). In former times, internships and service–learning efforts were among the most common examples of agricultural experiential learning which occurred outside the classroom. Today, however, there is increasing call to promote another type of experiential learning; undergraduate research. In an era where land–grant universities struggle with shrinking operating budgets and loud criticism for advancing the research enterprise at the expense of undergraduate education (Merkel, 2003), undergraduate research leverages discovery dollars toward teaching. In its landmark 1998 report, the Boyer Commission called for universities to take advantage of strong research resources to engage undergraduates in inquiry–based learning (Katkin, 2003). More recently, integrative federal funding initiatives from the United States Department of Agriculture (USDA), National Institute of Health (NIH), and

National Science Foundation (NSF) highlighted support for undergraduate teaching and learning embedded within the scholarship of discovery. Supervised research and mentorship of creative and original work by undergraduates has resonated with faculty, administrators and students. Research universities across the country are increasingly promoting, supporting and centralizing undergraduate scholarship via inquiry–based research (Katkin, 2003). In light of the changing nature of agricultural education and the increasing integration of undergraduate research into the curriculum in many agricultural colleges, examination of these learning contexts through a pedagogical lens is warranted.

Experiential learning, and thus learning through undergraduate research, is aligned with constructivist learning theory. Constructivism maintains that an individual's understanding comes through interaction and negotiation with their environment. Through experiences with open–ended, ill–structured problems, self–directed learners create knowledge as a means of interpreting the world around them, and validate this knowledge through discourse with others (Doolittle, 1999; Savery & Duffy, 2001). Psychological literature has defined problem solving, justified its value to educators and students, and established how to best incorporate problem solving into the student experience (Berardi–Coletta, Dominowski, Buyer, & Rellinger, 1995; Reder & Ritter, 1992). Undergraduate research, as a vehicle for student development, ultimately draws upon constructivist principles which yield scholarship through problem based learning.

Conceptual Framework

The conceptual framework for this study is grounded in the field of cognitive psychology. A great deal of research within psychology has been concerned with problem solving (Bransford & Stein, 1984; Davis, 1966; Gagne, 1964; Maier, 1970; Newell, Shaw, & Simon, 1958; Polya, 1946). After the initial decision to adopt problem solving skills in the learning environment, it is important to develop a model to follow when solving problems. The literature related to cognitive problem solving process has addressed multiple models to explain the problem solving process. The models are based on the work of Polya, Pietrasinski, Bransford

and Stein, Lockhead, and Whimbey. The early literature is based around the principals of artificial intelligence and mathematics; the theories have been transferred to education.

Before explaining the models of problem solving it is imperative that problem solving is defined. From the literature, many definitions of problem solving have been identified. Definitions of problem solving have included key concepts such as tasks, goals, mental processes, and attaining goals. Bloom and Broder (1950) defined problem solving as "the process by which the subject goes from the problem or task as he sees it to the solution which he regards as meeting the demands of the problem" (p. 7). Polya (1946) defined problem solving as "finding a way out of a difficulty, a way around an obstacle, attaining an aim that was not immediately attainable" (p. ix). Later, Woods (1987) defined problem solving as "the mental process that we use to arrive at 'best' answer to an unknown or some decision, subject to a set of constraints" (p. 55).

The literature related to cognitive problem solving process has addressed multiple models to explain the problem solving process. The models are based on the work of Polya, Pietrasinski, Bransford, and Stein, Lockhead and Whimbey. Polya (1946) utilized mathematics as the vehicle to develop and describe the problem solving process as four phases the learner must do in order to solve problems. The four phases are: (a) understand the problem, (b) make a plan, (c) carry out the plan, and (d) look back at the solution. Polya's work was primarily in the field of mathematics and based the theory on making individuals think.

While working on theories of efficient thinking, Pietrasinski (1969) developed a four step problem solving model. His model operated on these four foundational steps; (a) confrontation by a problem, (b) search for the solution, (c) the solution of the problem or the admission of failure, and (d) final checking of and perfecting the solution. Pietrasinski's straightforward model is depictive of a linear approach to solving problems.

Building on the concepts of Polya, Bransford and Stein (1984) developed a very similar model of problem solving, titled IDEAL. The model IDEAL included five steps (a) identify the problem, (b) define and represent the problem, (c) explore possible strategies, (d),

act on the strategies, and (e) look back and evaluate the effects of your activities. Bransford and Stein's IDEAL problem solving model paved is one of the most recent models of problem solving.

While very similar to Pietrasinski's model, Lockhead and Whimbey (1987) developed a four step model using research comparing experience and novice problem solvers. After analysis, the expert problem solver uses these four steps: (a) the expert assembles information from the problem, (b) plans the problem solution, (c) solves the problem, and (d) checks the solution. When this model is applied for novice learners, frequent failure is a result of the lengthy process involved in becoming an expert problem solver (Lockhead & Whimbey, 1987).

Purpose and Objectives

The purpose of this study was to review and synthesize relevant literature and theoretical frameworks relating to constructivism and its application to teaching via undergraduate research in agriculture. Specific objectives were to (a) identify and define the conceptual framework of constructivism, and (b) explore constructivist learning theory in the context of undergraduate research.

Methods and Procedures

This study employed a historical research methodology. This method involves systematic collection, evaluation and synthesis of data to describe, explain, and thereby understand events and conceptual connections that have happened previously (Fraenkel & Wallen, 1993; McMillan, 2000; Pyrczak, 2005). Concepts were elicited from sources with primary emphasis on constructivism and its role in authentic, problem–based learning and/or social facilitation of learning that occurs in undergraduate research. The following sources were used to gather data for this study: PsycINFO, PsycARTICLES, ERIC Documentation Reproduction Service, NACTA Journal, and Journal of Agricultural Education. Keyword search identifiers included problem solving, agriculture, cognitive process, constructivism, experiential learning, undergraduate research, and self–regulated learning. Studies appearing in these references

were identified through online database searches completed via the university library system and Google Scholar.

Results and Findings

Identification of the theoretical framework of constructivist learning theory.

Constructivism is a theory of learning in which learners actively construct their own knowledge as a result of their experiences (Doolittle & Camp, 1999; Savery & Duffy, 2001). It serves as the basis for experiential learning, which has long been a feature of undergraduate agricultural curricula for decades (Knobloch, 2003; Roberts, 2006). John Dewey, widely known as the father of experiential education, was a major contributor to constructivism. His view that each student's contextual learning experiences are unique and influenced by prior experience (Dewey, 1938) is a major feature of constructivist learning theory and grounds later work by Kolb (1984).

From an epistemological perspective, constructivism is based on a philosophy that reality is both subjective and relative, and is therefore personally unique. Although reality exists separately from experience, an individual's understanding is generated only through their interactions with the environment (Doolittle, 1999; Einstein & Infeld, 1937). Therefore, it is impossible to consider what is learned separately from how it is learned (Savery & Duffy, 2001).

A central proposition of constructivism is that knowledge is not gained through passive absorption, but rather, that individuals must take dynamic ownership of their personal creation of knowledge. Only through active processing can individuals attempt to seek meaning (Driscoll, 2005). This active processing, or cognition, is an adaptive process that allows learners to postulate and generate appropriate behavior for a given environment and generalize knowledge for future situational contexts (Doolittle & Camp, 1999).

Through constructivism, learners synthesize knowledge gained through experience to form an integrated view of how the world operates. These are organized as schemes, or groups of thoughts or behaviors that can be used to respond to certain environmental stimuli or generalized for new situations. Essentially,

these are working hypotheses which explain the world and serve as personal codes of conduct. Piaget (1977) posited that when individuals interact with their environment, new knowledge must be reconciled through the processes of assimilation and accommodation. Assimilation results in modification of one's perceptions of the environment to fit a scheme, while accommodation results in modifying a scheme to fit the environment (Ormrod, 2008). Learning is largely the result of accommodation, but requires assimilation as a precursor; the learner must be able to relate experiences to existing schemes before they can learn from them.

Another major tenet of constructivism is that knowledge is shaped through social negotiation and through evaluation of scheme viability (Savery & Duffy, 1995). Interaction and discourse allow for exposure to alternative views and serve as the primary mechanism for testing learner understanding (vonGlaserfeld, 1989). Group members may also serve the role of mentor or model, which can further guide knowledge creation.

In addition to social facilitation, constructivism emphasizes the role of learner reflection in evaluation of personal knowledge. Reviewing experiences and self–questioning can help resolve or unearth schematic discrepancies which may have gone unnoticed at the time. Through social interaction and individual reflection, learners arrive at knowledge which is the most viable interpretation of their experiences (Savery & Duffy, 1995).

Exploration of constructivist learning theory in the context of undergraduate research.

Undergraduate research is a form of experiential learning that extends a student's knowledge to scholarly application (Kinkead, 2003). It can be broadly defined to include scientific inquiry, creative activity and scholarship. Within the agricultural sciences, it is understood to result in the production of original work which is informed by previous work and is built upon by other scholars, is subjected to critical evaluation by peers who represent the expertise of the profession or discipline, and is publicly disseminated (Glassick, 2000).

Undergraduate research naturally lends itself to constructivist learning theory. It is a form of problem–based learning (Barrows, 1992; Savery & Duffy, 1995), where learning is driven by challenging, open–ended, ill–structured questions and is facilitated by senior group members. As such, the parallels between the scholarship of discovery and constructivism are clear; both acknowledge the importance of prior knowledge in the meaning–making process, both emphasize creation of new knowledge through active questioning, and both rely on peer review to validate new understanding. When viewed through a constructivist lens, students engaged in research actively take ownership of an authentic learning task and faculty members serve as facilitators for knowledge creation. As they are mentored by their peers, students undergo what Collins et al. (1989) termed a 'cognitive apprenticeship' which develops them as self–regulated learners.

Several authors have proposed pedagogical recommendations for using constructivism in a teaching environment (Doolittle, 1999; Lebow 1993). These can be summarized to two major considerations: (a) Learning should be authentic and student–centered, and (b) while understanding may be highly individualistic in nature, it is derived through social negotiation. Both of these factors are examined below, framed within the context of undergraduate research.

Learning should be authentic and student–centered.

A central premise to constructivism is that learning should take place in real–world environments. This facilitates active, rather than passive, learning, and addresses the individualistic nature of knowledge creation. While engaged in undergraduate research, students grapple with the same types of cognitive challenges experienced by faculty and graduate student researchers and contribute meaningfully to the larger scientific effort. Their knowledge, skills and scholarly output are monitored in the same fashion as that of their senior peers (Merkel, 2003). When knowledge is created in an authentic context, it is longer–lasting and more viable than if derived as a result of an exercise without real–world consequence (Doolittle & Camp, 1999). This deep learning requires the student to utilize higher order thinking (Bloom et al., 1956) to critically evaluate and solve multidisciplinary problems.

Constructivists believe that cognition and knowledge creation are adaptive functions which allow for enhanced ability to assess and positively react to given environments. Therefore, learning contexts must acknowledge and build upon prior knowledge and be relevant so that the learner is willing to change their current way of thinking (Doolittle, 1999). Exploration of previous literature through written review or discourse with peers allows students to frame their understanding of a subject before the experimental or active questioning portion of their project begins. Similarly, individual research projects allow students to explore subjects of particular interest to them, providing greater relevancy and motivation for learning. Students are able to connect their current research experience to their previous background and future career goals, thereby attributing greater personal benefit to the learning process.

Ultimately, students should be encouraged to become self–regulatory, self–mediated and self–aware through their undergraduate research experiences. Although constructivism promotes knowledge construction as communal, learning experiences should emphasize development of each individual student's ability to develop both cognitively and metacognitively into a self–regulated learner (Bandura, 1989; Lebow, 1993). Undergraduate research provides faculty mentors with an opportunity to coach students in development of personal autonomy in the learning process which will persist through the student's lifetime. Through its inquiry–based approach to knowledge creation and expectation that knowledge comes often from making mistakes, the research environment naturally lends itself to metacognitive development. Research staff model self–regulation skills such as goal–setting, critical analysis of self–progress, and self–questioning; students subsequently develop similar automatic feedback loops with coached practice (Lebow, 1993; Zimmerman, 2009).

Learning should involve social negotiation and mediaton.

Engaging students in undergraduate research promotes interactive, dynamic construction of knowledge and inclusion in a community of scholars as proposed by Boyer (1990). Understanding is inherently individual; personal knowledge creation depends on the learner's prior knowledge and interpretation of events. However, an individual's understanding is shaped through social facilitation. Faculty mentors provide for and encourage multiple perspectives and representations of content. The cooperative learning context provided by undergraduate research can expose students to different points of view, including those with which they disagree, in a supportive environment. As a result, students consider a problem from various perspectives (Lebow, 1993) and arrive at knowledge which best models their experiences and social interactions (Doolittle & Camp, 1999).

Faculty mentorship is key to the undergraduate research experience. In an extensive longitudinal study, Astin (1993) found that the two most important factors in student cognitive and affective development and learning were the quantity and quality of interaction with faculty outside the classroom. During the undergraduate research project, faculty mentors assume responsibility for scaffolding the knowledge creation process, rather than act as 'knowledge conduits' (Doolittle & Camp, 1999). Their role is to create experiences which challenge and develop the student appropriately in cognitive, affective and behavioral domains. This student–oriented approach, and commitment to the student learning experience, is a central assumption of constructivism.

Summary and Implications

Experiential learning is a fundamental component of agricultural science curricula, and is aligned with constructivist learning theory. Undergraduate research, a particular type of experiential learning context, can be viewed from a constructivist perspective. Constructivism's two primary tenets of active, authentic, student–based learning and knowledge creation through social interaction, lend themselves readily to undergraduate research. When students are actively engaged in undergraduate research, they enjoy the learning process. Students develop higher–order thinking skills and reason more efficiently because they are challenged to operate within an authentic, real–world context. Through interaction with faculty mentors and peers they develop their

social and interpersonal skills within the scientific hierarchy and learn what is expected for successful scholarship. Because they create knowledge from experience with open–ended, ill–structured problems, they develop their ability to generalize knowledge to other subjects and circumstances. Finally, through their interaction with hypothesis– or problem–based research, they become more metacognitively aware, achieving greater self–regulatory learning skills through appreciation of directed inquiry. These strengths are all inherent in a paradigm of constructivism.

Yet constructivism is not without its challenges, and these extend to the context of undergraduate research. Due to the open–ended and individualistic nature of constructivist learning contexts, students may take different meanings away from the same experience, and these meanings may not be what the faculty member intended. As facilitators, mentors give up some control over the learning process, and instead rely upon the student to shoulder this responsibility. While this ultimately promotes self–regulated learning, some faculty can experience difficultly as they adjust to the new

paradigm of instruction. Further, constructivism's two major tenets, that learning is active and individual, and that it must be facilitated through mentorship and social interaction, make undergraduate research incredibly inefficient across an institution. Although students are often hand–picked, highly motivated and highly–qualified, they still require significant coaching and input of resources. Student learning necessarily proceeds at different rates and assessment is difficult to standardize across experiences. As a result, mentoring undergraduate students is extremely time consuming, which slows down the research enterprise (Malachowski, 2003).

Despite these challenges, undergraduate research provides an excellent opportunity for faculty mentors to practice constructivist principles outside the traditional classroom setting, and the benefits for student learning are clear. Agricultural educators should take advantage of parallels between constructivism and the scholarship of discovery to enhance self–regulated learning of students and further integrate institutional research and teaching missions.

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