Animal sciences undergraduate education since the ASAS centennial: a national survey and scoping review

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ABSTRACT: The rapid pace of advancement in animal sciences is drastically changing conditions for undergraduate teaching and learning in the discipline. Shortly after the American Society of Animal Science (ASAS) centennial, we conducted a national survey of 90 faculty instructors from 49 academic institutions to assess their perceptions of emerging teaching topics. Participants rated 18 learning outcomes (LO) and 16 types of courses and experiences (CE) with respect to their importance and the adequacy of available offerings. This study presents the results of the survey along with a scoping review of animal sciences teaching and learning publications since 2008 ($n = 71$). Results indicated that discipline-specific competencies and core experiential learning remain central to animal sciences teaching and identified several distinct needs for research. Namely, we suggest that future research in animal sciences teaching and learning 1) develop animal-science-specific expertise on a greater variety of pedagogies, 2) validate improved methods for assessing transferable skills, 3) expand pedagogical knowledge of emerging topics (e.g., sustainability, data science, welfare science, social science), and 4) deepen and broaden animal sciences' teaching and learning identity through theory-building work and collaborations across instructors, disciplines, and institutions.

Key words: animal science, experiential learning, pedagogy, teaching, undergraduate

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INTRODUCTION

In an American Society of Animal Sciences (ASAS) centennial review of animal sciences teaching, Buchanan (2008) called for no less than a nationwide re-evaluation of the learning outcomes, course experiences, and assessment programs in animal sciences undergraduate programs. The conditions for teaching and learning animal sciences have changed so drastically, he argues, that departments must update teaching practices or risk becoming obsolete (Thaxton et al., 2003; Buchanan, 2008). Indeed, attitudes surrounding animal care and use are shifting and food production systems are becoming more complex (Meyer, 1993; Thornton, 2010). Practitioners of animal sciences now occupy a more biotechnological, global, and multicultural space than ever before (Britt et al., 2008). Likewise, today's undergraduate animal sciences enrollees have dramatically different interests, goals, and backgrounds than students of past decades (Edwards, 1986; Reiling et al., 2003; Peffer, 2010).

In response to changing needs, departments of animal sciences must continually engage in relevant teaching practices and assessment relying

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on discipline-based educational research (DBER), reflective practices, and scholarship of teaching (SoTL) (Kreber, 2002; McNamara, 2009; National Academies of Sciences, Engineering, and Medicine, 2018). During most of the 20th century, professional development opportunities in animal sciences were limited to symposia and informal interactions—for the most part escaping empirical analysis, rigorous peer scrutiny, and archival in journals (Buchanan, 2008). The lack of an adequate peer-review process slowed progress substantially. Only recently, as departments of animal sciences renegotiate the distinct public role they serve, has scholarly understanding of undergraduate education in the discipline begun to develop (Kezar, 2004; Buchanan, 2008). As more and more instructors combined their research and teaching acumen to address SoTL and DBER topics, the volume of research has grown substantially. However, most of the research thus far is situated within a single classroom, instructor, and/or institution. To our knowledge, no prior work has systematically described emerging practices in animal sciences teaching and learning at a broader level, across universities and within the burgeoning scholarly literature. The objectives of our research were consequently to:

1) describe U.S. faculty instructors' views of learning outcomes (LO) and course experiences (CE) with respect to their importance and the adequacy of available offerings in their current program.
2) examine correlations in faculty instructors' ratings of the importance of LO and CE in their current program.
3) quantify the volume of research on specific LO and CE themes through a scoping review of publications on teaching and learning in animal sciences since the ASAS centennial (2008–2020).

MATERIALS AND METHODS

Survey Administration and Instrumentation

All survey procedures were approved by the Institutional Review Board. A research team of experienced instructors created a quantitative questionnaire including LO and CE frequently mentioned by colleagues, in the literature, and at conferences (Supplementary Appendix 1). After beta testing and refining the survey with a small sample, researchers administered the survey instrument in paper form during two conferences: The National Conference on Teaching and Learning in the Animal Sciences, University of Wisconsin, Madison, WI in June 2012, and the Teaching Workshop at the American Dairy Science Association-American Society of Animal Sciences Joint Annual Meeting, Indianapolis, Indiana in July 2013.

The anonymous survey included five sections. In Section 1, participants rated the importance of a list of 18 LO on an anchored scale of 1 (not important at all) to 5 (a great deal of importance) and the adequacy of each LO in their current academic program on a scale of "good as it is," "need more," "no opinion," and "need less." Section 2 used the same scoring scales to assess the importance and adequacy of 16 CE. Topics assessed through Sections 3 and 4 included basic information on participants' teaching experience and teaching in their department. Finally, Section 5 evaluated institutional and professional demographics.

Survey Participants

One hundred forty-eight participants completed the survey: 79 in 2012 and 69 in 2013 (Table 1). For the 14 participants who repeated the survey in 2013, we found no statistical differences between 2012 and 2013 responses and subsequently retained only 2013 values. Because our focus was on faculty members from United States, we excluded

Table 1. Demographics of the survey participants

Category	N	%
Gender		
Female	36	40
Male	54	60
Citizenship		
US	74	85
Other	13	15
Race/ethnicity		
White	71	86
Minority	12	14
Undergraduate degree completion		
US	78	89
Other	10	11
Graduate degree completion		
US	84	95
Other	4	5
Family educational history		
First generation to attend college	36	47
One or both parents has a college degree	41	53
Professorial rank		
Assistant professor	32	36
Associate professor	26	29
Full professor	32	36

N = 90 instructors surveyed at two national conferences in 2012–2013.

responses representing faculty from foreign universities (n = 22), academic staff members (n = 9), postdoctoral research associates (n = 2), graduate students (n = 6), and other professionals (n = 1). We further excluded several incomplete responses (n = 4). The final dataset included 90 professors from 49 animal and dairy science departments from 38 U.S. states (AL, AZ, CT, FL, GA, HI, IA, IL, IN, KS, KY, LA, MA, MD, ME, MI, MN, MS, MT, NC, ND, NE, NH, NV, NY, OH, OK, PA, SD, TN, TX, UT, VA, VT, WA, WI, WV, and WY). The majority of respondents (85.6%, N = 77) represented research-focused doctoral institutions (Carnegie Basic Classification 15 or 16). Participants reported a median of 40% teaching appointment (IQR = 25, 70), 20% research appointment (IQR = 0, 50), 0% extension appointment (IQR = 0, 0), and 0% administrative (IQR = 0, 19) appointments.

Survey Statistical Analysis

We conducted all analyses in SAS version 9.4 (SAS Institute, Cary, NC) and created visualizations in R (R Core Team, 2019). First, we computed descriptive statistics for participants' demographic data, the perceived importance of LO and CE, perceptions of teaching and learning in their departments, and perceived adequacy of LO and CE in the participants' academic programs. Next, we began dimensionality reduction for the 18-item LO and 16-item CE questionnaires. We verified sampling adequacy through the Kaiser–Meyer–Olkin (KMO) statistic (0.80 and 0.64 for LO and CE, respectively) (Kaiser, 1974). Then, we conducted a principal component analysis (PCA) on responses to each questionnaire using the PROC FACTOR procedure. Using the Kaiser criterion (eigenvalue > 1), we retained four PC explaining 66% of the variance in LO responses and five PC accounting for 67% of variance in CE responses (Stevens, 2002). We excluded four items on the LO questionnaire and two items on the CE questionnaire due to low communality (<0.49). Each set of extracted factors underwent varimax rotation to enhance the interpretability of the principal components (PC). Finally, we calculated Spearman correlations among PC scores of LO and CE in our sample using the PROC CORR procedure of SAS.

Scoping Review and Coding Methods

To integrate recent scholarly literature into our analysis, we conducted a scoping review of articles on teaching and learning in animal sciences and applied LO and CE categories discovered through our PCA as a priori themes for provisional coding (Saldaña, 2009). Our search identified 71 relevant full-text articles published between 1 January 2008 and 5 January 2020. Detailed information on our scoping review and qualitative methods is available in the appendix.

RESULTS AND DISCUSSION

Institutional and Professional Demographics of Survey Participants

Table 1 describes the professional demographics of the 90 U.S. animal sciences faculty survey respondents. The sample appeared balanced in their self-descriptions of gender and professorial rank, however, a large majority described their race as "white." Most participants were born in the United States and many completed both undergraduate and graduate degrees domestically. Many (47%) indicated being the first generation in their family to attend college. Figure 1 shows participant beliefs and practices related to their own teaching. Most participants indicated that they currently prioritized teaching in their career and believed themselves to have been successful in teaching. To a lesser extent, participants reported prioritizing administration, research, and extension in their careers. Most instructors expressed an interest in improving their teaching and many reported regular attendance at teaching-related programs. Roughly half of participants believed their classes to be student-centered, although a majority of participants claimed to use student feedback in course improvement efforts.

Minimal past research has described the demographic profile of U.S. animal sciences faculty. Compared with Casey and Plaut's (2003) national survey of ADSA/ASAS members, our sample showed a similar lack of racial/ethnic diversity but greater apparent balance across genders. Despite persisting structural barriers and demographic inertia, the participation of diverse gender, racial, and ethnic groups appears to be slowly increasing among agricultural science academics (National Center for Science and Engineering Statistics, 2018). The large fraction of women in our sample may also be attributable to the relatively greater contribution of women to teaching and service activities (Guarino and Borden, 2017), especially at research institutions (Singell et al., 1996). Animal sciences' traditional values—criticized as androcentric, individualistic, and overly-focused on economic efficiency—continue to bias the professional

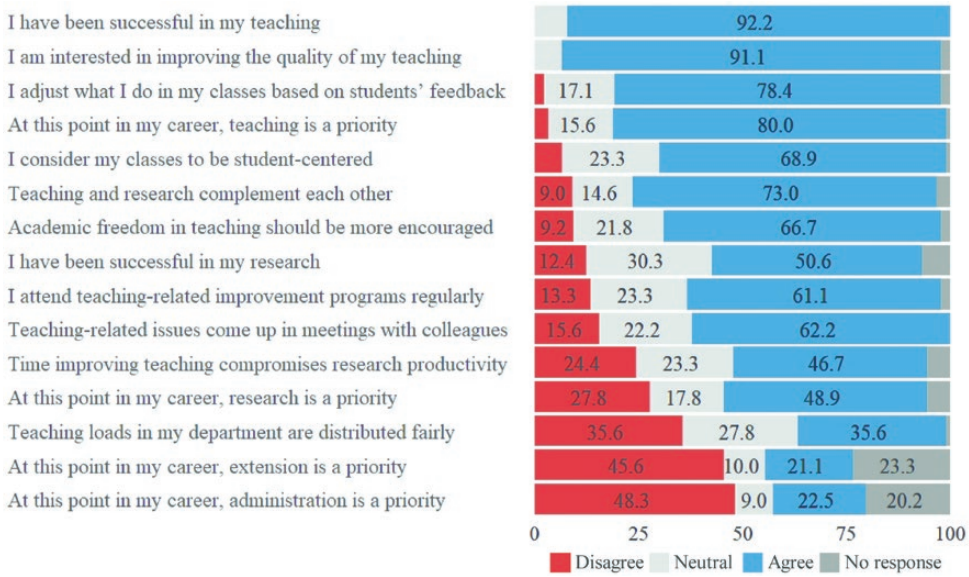

Figure 1. Instructor beliefs and perceptions related to their personal teaching practice. *N* = 90 instructors surveyed at two national conferences in 2012–2013.[1]

[1]Percentage in each of four categories based on participants' level of agreement on a scale of 1 to 10: 1–4 (disagree), 5–6 (neutral), 7–10 (agree), or N/A (no response).

reward structure against diversity (Schillo, 1998; Wattiaux et al., 2010).

Although our participants overwhelmingly represented research-active doctoral institutions, their responses demonstrated a clear focus on teaching and scholarly teaching across a wide range of declared appointments. Administering surveys at teaching events at scientific conferences may likely have selected for this type of respondent. Still, across institutional types and disciplines, faculty on average spend the majority of their working time on teaching-related tasks (FSSE, 2010), though they differ in their commitment to scholarly teaching (Richlin, 2001). Indeed, research has shown that instructor attitudes and beliefs surrounding teaching are stronger predictors of their use of student-centered practices than institutional or professional factors (i.e., class size, teaching appointment, institution type; Yoder et al., 2019). The majority of our participants reported engaging in some scholarly teaching activities such as discussing teaching with colleagues, utilizing learner-centered teaching methods, and incorporating student feedback. However, we did not assess their teaching practices, professional development, or engagement in teaching research in great depth.

Instructor Ratings of the Importance and Adequacy of Learning Outcomes (LO)

Table 2 displays eigenvalues and variance explained for selected principal components of the importance of LO. Principal component analysis identified four PC for the importance of LO which we termed practical agribusiness competencies (LO-1), analytical, collaborative skills (LO-2), multimodal communication skills (LO-3), and discipline-specific competencies (LO-4) based on

Table 2. Eigenvalues, percentage of variance, and cumulative percentage of variance for the identified principal components on instructors' perception on importance of learning outcomes and types of courses and experiences

PC[a]	Eigenvalue	%var.	Cumulative %var.
Importance of learning outcomes			
LO-1	5.20	37.2	37.2
LO-2	1.73	12.4	49.5
LO-3	1.23	8.8	58.3
LO-4	1.12	8.0	66.3
Importance of types of courses and experiences			
CE-1	3.46	24.7	24.7
CE-2	1.96	14.0	38.7
CE-3	1.47	10.5	49.1
CE-4	1.37	9.8	58.9
CE-5	1.08	7.7	66.6

N = 90 instructors surveyed at two national conferences in 2012–2013.

[a]LO-1, practical agribusiness competencies; LO-2, analytical, collaborative skills; LO-3, multimodal communication skills; LO-4, discipline-specific competencies.

CE-1, core experiential learning; CE-2, Internet-based learning; CE-3, community-integrated learning; CE-4, global & research experiences, CE-5, lecture-based and capstone learning.

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the common characteristics of items on each PC (Table 3). Figure 2 summarizes instructor perceptions of the importance of LO and the adequacy of teaching with respect to LO at their institution.

Multimodal communication skills were rated among the most important, yet the majority of instructors described the teaching of these LO as adequate at their institutions. In contrast, discipline-specific competencies were rated both as highly important and greatly in need at animal sciences teaching institutions. Instructors uniformly agreed that analytical, collaborative skills are important. However, in many cases, they felt that their institutions currently taught such skills at an acceptable level. Finally, instructors diverged on their perceptions of the importance and adequacy of practical agribusiness competencies, the principal component explaining the greatest amount of variance. Instructors rated agricultural policies, language skills, and intercultural competence as relatively important skills, however, issues related to international agriculture appeared to be less favored.

More and more research has called attention to the importance of communication, interpersonal, and practical business skills in life science (Schillo, 1997; Fischhoff, 2013). Such skills, i.e., transferable skills, are among the most sought-after by agricultural and natural resources industry leaders (Easterly et al., 2017), and employers report that recent graduates are only "somewhat" prepared by undergraduate degrees (Alston et al., 2009). In animal sciences, signature pedagogies such as judging competitions, quadrathlons, and other industry-partnered events are common means to integrate development of transferable and scientific skills (Kauffman, 1992; Wattiaux, 2013). Similarly, the increasing popularity of active, learner-centered methods in animal sciences has positive implications for implicitly developing transferable skills (Yamada, 2018; Erickson et al., 2020). Still, few undergraduate scientific curricula target and assess these learning objectives explicitly through required coursework (Brownell et al., 2013). In the absence of curricular integration of transferable skills in animal sciences, our instructors' mixed ratings on the importance and adequacy of LO-1 and LO-3 may reflect varying evaluative frames of reference. Greater integration of communication, interpersonal, and practical skills into required courses and more rigorous assessment (e.g., the use of portfolio evidence) may assist departments of animal sciences in understanding and improving student outcomes in this area (Williams, 2002; Rees and Sheard, 2004).

Table 3. Principal component loadings and scores for instructors' perception of the importance of learning outcomes (LO)

	Principal component loading[a]			
Principal component	LO[b]-1	LO-2	LO-3	LO-4
LO-1 – practical agribusiness competencies				
International agricultural systems	**0.86**	0.20	0.02	0.09
State and federal policies related to agriculture	**0.74**	0.20	0.30	0.04
International agri-business marketplace	**0.81**	0.17	0.06	0.14
Languages other than English	**0.74**	0.07	0.19	0.07
Intercultural competence	**0.64**	0.48	–0.12	0.07
LO-2 – analytical, collaborative skills				
Ability to apply, analyze, and evaluate	0.14	**0.63**	0.53	–0.14
Problem-solving – as an individual	0.00	**0.76**	0.24	0.22
Problem-solving – in team settings	0.22	**0.64**	0.36	–0.08
Decision-making in the face of uncertainty	0.38	**0.59**	–0.11	0.24
Ethical reasoning and action	0.37	**0.71**	0.01	0.11
LO-3 – multimodal communication skills				
Oral and written communication	0.20	0.24	**0.75**	0.14
Interpersonal communication	0.04	0.03	**0.82**	0.12
LO-4 – discipline-specific competencies				
In depth animal science	0.03	0.14	0.19	**0.77**
The scientific method	0.20	0.05	0.01	**0.79**

N = 90 instructors surveyed at two national conferences in 2012–2013.

[a]Rotated factor patterns expressed as principal component loadings.

[b]LO, learning outcomes.

Items "Gain life-long learners' skills" (0.23), "Demonstrate an ability to remember, understand, and explain" (0.38), and "Leadership development skills" (0.46), "Gain appreciation of global issues in food and agriculture" (0.49), were removed from the analysis due to lower communality values.

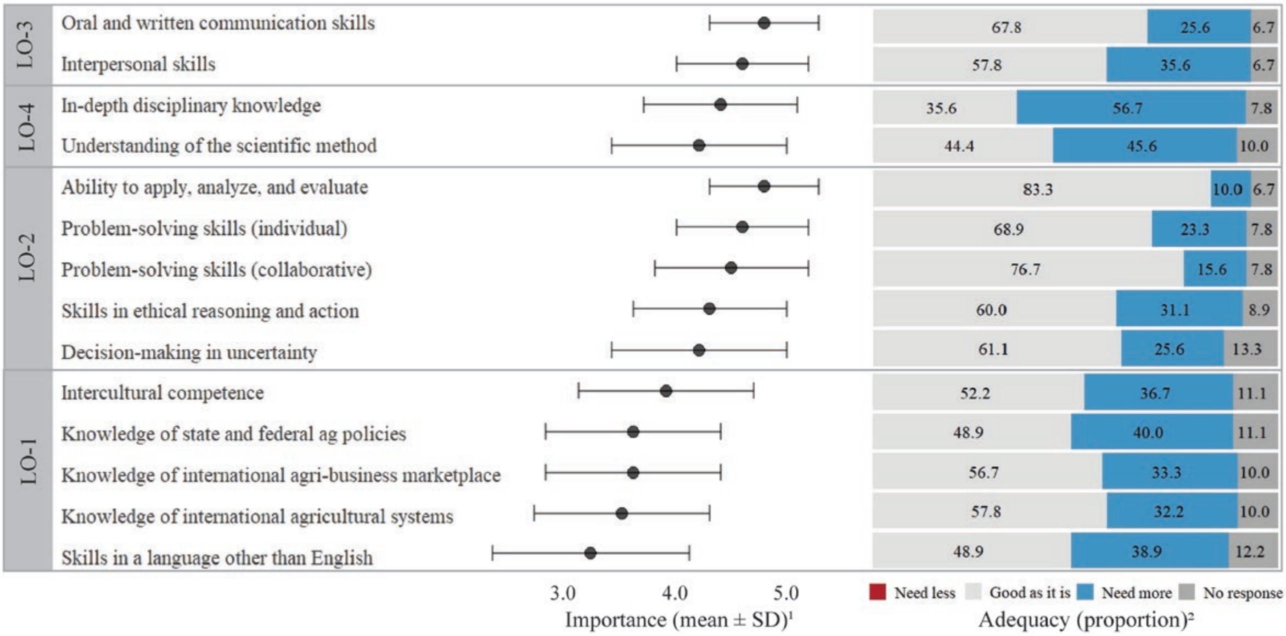

Figure 2. Instructor perceptions of the importance of selected learning outcomes (LO) and the adequacy of teaching with regard to LO at their institution. N = 90 instructors surveyed at two national conferences in 2012–2013.

[1]Mean ± SD of instructor perception of importance on a Likert scale from 1 (not at all) to 5 (a great deal).

[2]Percentage of instructors within each category representing their perception of the adequacy of teaching with regard to each LO at their institution.

[3]LO-1, practical agribusiness competencies, LO-2, analytical, collaborative skills, LO-3, multimodal communication skills; LO-4, discipline-specific competencies.

Note: Sorted by mean principal component score, item score.

Scientific faculty uniformly value discipline-specific competencies and analytical skills and our respondents appeared no different (Stedman and Adams, 2014). While employers emphasize broad, flexible analytical skills, many science faculty focus primarily on delivering adequate content—viewing teaching scientific process skills (i.e., the analytical, self-regulatory, collaborative aspects of science) as beyond their responsibilities or abilities (Coil et al., 2010; National Research Council [NRC], 2011). This may explain why our respondents rated both LO-2 and LO-4 items as highly important but emphasized teaching needs for content-focused discipline-specific competencies. Alternatively, the pace of advancement in animal sciences may necessitate more focus on developing pedagogical content knowledge for new technologies and ideas (Kauffman, 1992; Hill et al., 2008). More research is warranted to consider the unique expertise of faculty in making instructional decisions that meet the needs of both students and employers.

Instructor Ratings of the Importance and Adequacy of Courses and Experiences (CE)

Table 2 displays eigenvalues and variance explained for selected principal components of the importance of CE. We identified and subsequently named five PC for the importance of CE: core experiential learning (CE-1), internet-based learning (CE-2), community-integrated learning (CE-3), global and research experiences (CE-4), and lecture-based and capstone courses (CE-5; Table 4). Figure 3 summarizes instructor perceptions of the importance of CE and the adequacy of teaching with respect to CE at their institution.

Instructor ratings of the importance of CE showed a great deal more variation within PC than ratings of the importance of LO. For example, CE-1 explained the greatest degree of variation among instructors, yet on average was rated most highly important and most needed. Instructors uniformly supported hands-on laboratories and internships as a teaching modality but varied more substantially in the value ascribed to other experiential activities. Most instructors rated internet-based learning (CE-2) as highly important and needed, with a small fraction of dissenters driving apparent variation. Community-integrated learning (CE-3) through real-world, project-based activities appeared more important to instructors than service learning, although curricular offerings for service learning appeared to be in greater need. Regarding CE-5, instructors rated capstone learning highly important but adequately taught at their institutions. Powerpoint-based lectures—the most contentious CE topic—split instructors regarding both

Table 4. Items and principal component loadings for instructors' perception on importance of types of courses and experiences (CE)

Principal component	Principal component loading				
	CE[a]-1	CE-2	CE-3	CE-4	CE-5
CE-1 – core experiential learning					
Hands-on laboratories	**0.64**	0.09	–0.19	0.00	0.24
Discussion of preassigned readings	**0.48**	0.35	0.30	0.17	–0.26
Computer simulation, modeling	**0.58**	0.41	0.28	–0.12	–0.14
Collaborative work	**0.70**	0.11	0.24	0.17	–0.05
In-country internships	**0.72**	–0.31	0.16	0.15	0.26
CE-2 – Internet-based learning					
Using the internet as a learning tool	0.02	**0.90**	0.05	0.04	0.10
Using the internet as a communication tool	0.10	**0.87**	0.06	0.05	0.11
CE-3 – community-integrated learning					
Service learning	0.09	0.27	**0.73**	0.02	–0.13
"Real-world", project-based activities	0.17	–0.07	**0.77**	0.17	0.22
CE-4 – global & research experiences					
International experience (field-trip, study abroad, etc.)	0.18	–0.07	0.42	**0.62**	–0.03
Internships abroad	0.27	0.00	0.19	**0.81**	0.00
Undergraduate research experience	–0.12	0.13	–0.16	**0.81**	0.11
CE-5 – lecture-based & capstone learning					
Powerpoint-based lectures	0.14	0.26	–0.28	0.07	**0.69**
Capstone projects	0.05	–0.01	0.40	0.03	**0.74**

N = 90 instructors surveyed at two national conferences in 2012–2013.

[a]CE, types of courses and experiences.

Items "Writing-intensive courses" (0.33), and "Business and human resource management" (0.45), were removed from the analysis due to lower communality values.

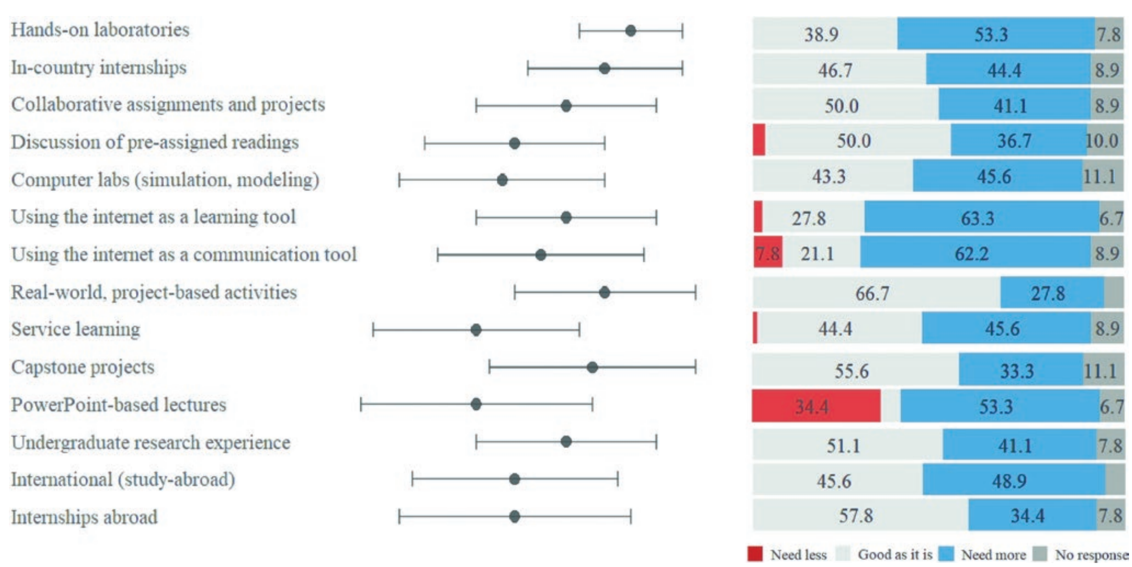

Figure 3. Instructor perceptions of the importance of selected courses and experiences (CE) and the adequacy of teaching with regard to CE at their institution. *N* = 90 instructors surveyed at two national conferences in 2012–2013.

[1]Mean ± SD of instructor perception of importance on a Likert scale from 1 (not at all) to 5 (a great deal).

[2]Percentage of instructors within each category representing their perception of the adequacy of teaching with regard to each CE at their institution.

[3]CE-1, core experiential learning; CE-2, Internet-based learning; CE-3, community-integrated learning; CE-4 = global & research experiences; CE-5, lecture-based and capstone learning.

Note: Sorted by mean principal component score, item score.

importance and adequacy of teaching (Figure 3). In our sample, instructor ratings of the importance of lecture-based learning were correlated with their views on capstone learning such that the two items composed a single principal component. This principal component (CE-5), which explained a relatively small amount of variance, represents a possibly artifactual finding due to PCA's assumption that the totality of variance is explained by components rather than partitioned into that explained by latent structures and that of unique error, as in factor analysis (Kaplan, 2009). Similarly, global and research experiences (CE-4) also appears to encompass a greater apparent variety in topics. On average, instructors rated CE-4 as important, but in many cases felt their institutions provided adequate teaching.

Hands-on, experiential learning has been the backbone of animal sciences pedagogy for over a century (CE-1, CE-3; Buchanan, 2008; Wattiaux, 2008). Practical needs have driven and organized learning across the diverse topics composing our discipline historically (e.g., genetics, nutrition, economics, agronomy) and accommodated emerging topics that promise to revolutionize the discipline (e.g., sustainability, data and computer science; McNamara, 2009; Erickson et al., 2020). Experiential learning in animal sciences will undoubtedly continue to evolve in the future. As demographics and funding sources change, many animal sciences departments are expanding offerings to provide continuing education and serve nontraditional student groups (e.g., placebound learners) through flexible online courses (Britt et al., 2008; McNamara, 2009). The demographics of traditional students are also shifting. Contemporary aspiring animal scientists are more diverse, more computer-savvy, and have less prior animal experience than students in past decades (Britt et al., 2008; Peffer and Ottobre, 2011). Our results indicate that many institutions, possibly through a large volume of teaching research, may be adequately updating experiential pedagogies to encompass these changing student needs and goals.

Powerpoint-based lectures have been the subject of much scrutiny as an animal sciences teaching modality (Mortensen and Nicholson, 2015; Erickson et al., 2020). Today's Powerpoint-aided lectures have strong historic roots—evolving from spoken-word and chalkboard presentations (Armour et al., 2016). Early departments of animal sciences, wrought from an industrial model of education, used lectures to disseminate information efficiently across large groups of students. Didactic lectures still enjoy widespread use in today's animal sciences undergraduate programs (Balschweid et al., 2014), although a great deal of research discredits their effectiveness at developing desired skills (Freeman, 2014; Wieman, 2014). In our analysis, Powerpoint-based lectures polarized instructors. Additional research is needed to understand instructors' motivations for choosing didactic lecturing and the preparation and support they receive for implementing lecture alternatives. Hybrid pedagogies such as active lecturing show promise as low-input strategies that can ease the transition to more learner-centered, effective instruction (Bernstein, 2018).

Correlations among Learning Outcomes (LO) and Courses and Experiences (CE) in the Instructor Survey

Table 5 presents Spearman correlation coefficients among instructors' perceived importance of LO and CE variables. Core experiential learning (CE-1) had a significant positive correlation with analytical, collaborative skills (LO-2); multimodal communication skills (LO-3); and discipline-specific competencies (LO-4). Community-integrated learning (CE-3) showed a strong positive correlation with practical agribusiness competencies (LO-1). Discipline-specific competencies (LO-4) had significant positive correlations with all CE except community-integrated learning (CE-3), and most strongly correlated with global and research experiences (CE-4), and lecture-based and capstone learning (CE-5). In contrast, all other LO were correlated with only one CE, with LO-2 and LO-3 equally associated with CE-1. These results indicate an overlap between instructor ratings of certain LO and CE, that is, that instructors who rated the CE as important were likely to rate the correlated LO as important as well, and the inverse. Results may further imply that instructors perceive specificity of certain LO to certain CE, with the exception of discipline-specific competencies (LO-4), which

Table 5. Spearman correlations among instructors' perceived importance of learning outcome (LO) and course/experience (CE) variables

	Learning outcomes[b]			
Courses/experiences[a]	LO-1	LO-2	LO-3	LO-4
CE-1	0.07	0.31**	0.31**	0.23*
CE-2	0.04	–0.01	–0.03	0.26*
CE-3	0.37***	0.19	0.01	0.06
CE-4	0.18	–0.07	0.05	0.35***
CE-5	–0.01	0.08	0.04	0.33**

N = 90 instructors surveyed at two national conferences in 2012–2013.

[a]CE-1, core experiential learning, CE-2, Internet-based learning; CE-3, community-integrated learning; CE-4, global & research experiences; CE-5, lecture-based and capstone learning.

[b]LO-1, practical agribusiness competencies; LO-2, analytical, collaborative skills; LO-3, multimodal communication skills; LO-4, discipline-specific competencies.

*p<0.05, **p<0.01, ***p<0.001

instructors perceived as more universally important across CE. Ceiling effects may have influenced results, as well as instructors' familiarity biases. Still, these associations offer a deeper look into the portrait of LO and CE valued by instructors.

Scoping Review of Learning Outcomes (LO) in Recent Literature

The results of our scoping review (Figure 4) showed a distinct focus on assessing discipline-specific competencies (LO-4) and relatively fewer publications addressing practical agribusiness competencies (LO-1), analytical, collaborative skills (LO-2), multimodal communication skills (LO-3). Researchers were steadfast in assessing discipline-specific competencies (LO-4) throughout our timeframe, whereas research assessing other learning objectives appeared more sporadic. A wide range of courses and student types were represented within each LO, indicating that researchers considered these outcomes relatively nonspecific. Publications often addressed several LO in tandem (n = 62).

The focus on discipline-specific competencies (LO-4) is unsurprising given that these skills have the longest tradition of educational measurement in our discipline (Taylor and Kauffman, 1983). Most papers, even those focused on unrelated skills, included a measure of discipline-specific competencies. This may be due to the ease of assessing such skills. Most animal sciences professors regularly assess discipline-specific competencies through quizzes and tests recorded in a gradebook. Because faculty hiring practices favor discipline-specific expertise (Wattiaux et al., 2010; NRC, 2011), instructors are skilled at identifying salient concepts and constructing suitable assessments. Further, instructors likely receive more support for investigating discipline-specific skills because the academic socialization of nonteaching colleagues and administrators inclines them to value content skills (Lortie, 1975; Grunspan et al., 2018). Whether or not the large volume of research assessing discipline-specific competencies translates into higher quality teaching offerings has yet to be determined.

Conversely, practical agribusiness competencies, analytical and collaborative skills, and communication skills gained popularity in formal animal sciences education during the late 20th century (Aaron, 1996; Haug, 1996; Orr, 1996). Agriculture faculty are less competent at teaching and assessing noncontent skills and rarely include them in regular assessment, making them less accessible as a measured variable (Burbach et al., 2012; Blickenstaff, 2005). According to Blickenstaff (2005), faculty in colleges of agriculture report lack of time, lack of resources, and lack of emphasis on teaching in the promotion and tenure process as the top three barriers to improving their teaching. Our scoping review indicates that many animal sciences faculty, faced with these constraints, are unable to develop the expertise and programmatic focus necessary to assess noncontent skills. To make progress in adequately teaching these skills, departments of animal sciences need to explicitly value these broader transferable competencies: in the curriculum, in promotion and tenure decisions, and in allocating resources (Wattiaux et al., 2010). Until then, partnerships with campus instructional resource centers, school of education faculty, or other expert collaborators may assist instructors in assessing valued skills (Karcher et al., 2013; Erickson et al., 2019). Given the importance ascribed to such skills by the experienced instructors in our sample (especially LO-3, LO-2), greater research is warranted on teaching these skills in undergraduate animal sciences in the coming decades.

	Total Pubs./Th.[4]	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20
LO1	13	0	0	0	1	0	3	2	1	0	1	2	3	0
LO2	20	0	1	0	5	3	2	1	2	2	0	2	1	1
LO3	21	0	0	1	4	1	4	2	3	0	2	2	1	1
LO4	46	2	4	4	5	5	6	1	3	3	3	4	5	1
CE1	45	2	0	2	6	6	5	4	4	1	1	5	7	2
CE2	17	1	1	1	2	3	1	0	2	2	0	2	1	1
CE3	8	0	0	0	1	1	1	0	0	2	2	0	1	0
CE4	12	0	0	0	0	1	3	1	0	0	1	1	5	0
CE5	15	0	0	2	2	2	2	0	1	0	1	1	3	1
Total Th./Yr.[2]		5	6	10	26	22	27	11	16	10	11	19	27	7
Total Pubs./Yr[3]		2	4	4	8	7	9	5	6	4	3	7	10	2

Figure 4. Frequency of teaching & learning publications coded within provisional themes by year. N = 71 publications.[1]

[1]LO-1, practical agribusiness competencies; LO-2, analytical, collaborative skills; LO-3, multimodal communication skills; LO-4, discipline-specific competencies.

CE-1, core experiential learning; CE-2, Internet-based learning; CE-3, community-integrated learning; CE-4, global & research experiences; CE-5, lecture-based and capstone learning.

Note: Represents the range from 1 January 2008 to 5 January 2020.

[2]Sum of codes per year.

[3]Sum of publications per year.

Scoping Review of Courses and Experiences (CE) in Recent Literature

Summary results for our scoping review of CE are presented in Figure 4. Results showed a defined focus on studies examining core experiential learning (CE-1) Relatively few publications assessed other forms of CE, although the number of publications within each category appeared to grow over the timeframe assessed. Studies often represented more than one CE (n = 59), and a range of LO were represented across each CE category.

The great volume of research on core experiential learning (CE-1) likely reflects its breadth: CE-1 is a broad category that not only applies to a wide range of animal sciences instructors and courses, but also has historic importance as a signature pedagogy (Wattiaux, 2008). Resurging interest in active learning for higher education during the early 21st century likely also contributed to the research volume by boosting interest and institutional resources for exploring experiential learning topics. Research on CE-1 in our scoping review examined debates (Roucan-Kane et al., 2013), team-based learning (Hazel et al., 2013), flipped classroom discussion-based learning (Wattiaux, and Crump, 2013; Arnold et al., 2018), Problem-based learning (Erickson et al., 2019), learning through hands-on laboratories (Bundy et al., 2019; Erickson et al., 2020), and university-guided internship programs (Peffer, 2012; Anderson, 2015). Instructors used experiential pedagogies across a wide variety of courses: from traditional courses in animal handling (Bobeck et al., 2013), to courses assessing emerging issues such as sustainability and international agriculture (Wattiaux and Crump, 2013; Grant et al., 2019).

Few publications made explicit reference to lecture-based and capstone learning (CE-5), although these are also popular strategies. The majority of science instructors—even those who use some active learning techniques—use lecture for a large fraction of class time (Stains et al., 2018). Given its widespread use and documented shortcomings, it is possible that instructors regard lecture-based learning as an implicit baseline and consequently make little mention of it in their scholarly publications (Mortensen and Nicholson, 2015; Erickson et al., 2020). It is possible that further research could enhance the quality of lectures as an instructional format. Jones (2007) and others have made the case that "good" lectures remain a valuable aspect of any teacher's toolbox. Efforts to improve lecture-based learning, however, typically center on replacing a fraction of lecture time with more collaborative, experiential strategies (Erickson et al., 2019). Thus, future research considering the interaction between lecturing and experiential pedagogies may be more useful than that assessing lecture alone.

Capstone experiences, which offer a culminating learning opportunity focused on integrative and practical skills, first emerged as an undergraduate animal sciences pedagogy during the late 20th century and are thus a relatively newer teaching strategy than didactic lecturing (Swanson, 1999; Nilsson and Fulton, 2002). Although capstone experiences can presumably include instructional modalities such as internships, research, study abroad, independent study, service learning, or collaborative courses, limited literature has characterized typical features of capstone courses in animal sciences (Hall and Wood, 2017). Capstone courses have great potential not only as a positive learning experience for students, but also as a means to assess key curricular outcomes through final projects or portfolios (Nilsson and Fulton, 2002). However, publications in our scoping review focused exclusively on student perceptions and satisfaction (Hall and Wood, 2017), circumventing questions related to skill assessment. Increasing the impacts of future research on capstone courses will likely require overcoming limitations similar to those described for LO-2 and LO-3: namely, finding the time, resources, and expertise needed to create and assess complex learning experiences.

The remaining less-researched topics, internet-based learning (CE-2), community-integrated learning (CE-3), and global and research experiences (CE-4), apply to a narrower range of courses and instructors compared with core experiential learning (CE-1) and lecture-based and capstone learning (CE-5), decreasing opportunities for research. The scarcity of published literature indicates that animal scientists, collectively, have limited contextual understanding of these teaching formats. Given the potential these CE hold for modernizing animal sciences teaching and developing valued skills (e.g., analytical thinking, intercultural competence, digital literacy), greater support for developing these CE is warranted (NRC, 2011). Because animal sciences teaching research has for so long existed in the margins, even small organized efforts can improve research productivity. For example, the noticeable increase in research on CE-4 during 2019 seems to be due in part to manuscripts solicited by NACTA for a special issue on global agriculture. No other special circumstances affected the results of our scoping review to our knowledge.

Internet-based learning (CE-2) promises to transform many of the unique challenges faced by animal sciences programs, as publications in our scoping review demonstrate. For example, online simulations could alleviate certain animal welfare concerns associated with training inexperienced animal scientists on handling and management techniques (Pulec et al., 2016). Virtual tours can allow larger groups of students to access facilities that geographical distance, safety concerns, or biosecurity concerns had previously rendered beyond reach (outside of review see Erickson et al., 2019). Computer-generated visualizations of complex structures or physiological processes could enhance their comprehensibility to students (Johnson et al., 2008; Bing et al., 2011; Oki et al., 2014). The internet also makes an excellent medium for supplemental study tools (Bing et al., 2011; Stewart et al., 2011; Maiga et al., 2013). The early efforts observed in our scoping review show that online learning can be effective in animal sciences courses, but the full benefits of technology-integrated learning are likely still to be realized by future researchers and teachers.

Community-integrated learning (CE-3), long a critical part of animal sciences extracurricular activities, has only more recently been integrated into required coursework. Service learning and real-world, project-based activities are promising strategies for improving university relations, meeting student needs for personal development, and providing a microcosm for practicing career-relevant skills (Feldpausch et al., 2019). For example, authors in our scoping review implemented community-integrated learning to achieve a variety of ends. Amstutz et al. (2010) involved students in political action projects in which teams created voter education resources on contentious issues in animal agriculture. As a result of this program, students reported greater understanding of the topics and greater civic engagement. In Brown and Payne (2017), students worked with local extension services to offer cattle artificial insemination clinics for high school students, with students reporting improved oral and written communication skills and understanding of core topics. Chang et al. (2013) suggested that animal sciences students might prefer study abroad programs incorporating service-learning components. Service-learning may also provide a real-world context for transdisciplinary, trans-institutional, or industry-partnered work (Karcher et al., 2018; Splan et al., 2018).

Global and research experiences (CE-4) are two formative aspects of undergraduate life. For many students, experiences internationally or with research during college may be their greatest exposure to these areas throughout their lives. Intentionally-designed, well-researched programs are thus vital to ensuring that such programs maximize positive outcomes and effectively meet the goals of the undergraduate curriculum. With respect to global experiences, recent publications in our scoping review showed a distinct focus on developing programs with shorter time spent abroad and greater effort expended at the home campus through pre- and/or postcoursework (Karcher et al., 2013; Bott-Knutson et al., 2019). Educators report that short-term (1–3 weeks) in-country visits can produce similar gains in intercultural competence at a lower cost to students (Chang et al., 2013). More recent publications showed progress toward more valid mixed-methods assessment of intercultural competence (Grant and Karcher, 2019), novel topics such as sustainability (Karcher et al., 2013), and novel synergies with learning communities, the extension system, and industry partners (Chang et al., 2013; Grant and Karcher, 2019). The existing body of research appears limited by the small number of publications and small number of programs assessed.

Our scoping review also showed positive developments in undergraduate research programs. Karcher and Trottier (2014) documented that a club science research project improved students' integration into the animal sciences community and their understanding of the scientific process. Jones and Lerner (2019) found that undergraduate research experiences significantly improved students' critical thinking skills. In particular, course-based undergraduate research experiences (CUREs) may be critical to improving equity and diversity in scientific fields (Hernandez et al., 2013). Compared with traditional independent, student-directed undergraduate research, CUREs overcome numerous structural barriers that serve to reinscribe hegemonic order and perpetuate inequities—including limited research opportunities, unconscious bias, financial and personal barriers, and conflicting cultural norms (Carlone and Johnson, 2007; Bangera and Brownell, 2014). Jones and Lerner (2019) observed gains in critical thinking ability for animal sciences students involved in CUREs versus those completing undergraduate research in the traditional format. Outside of our scoping review, Bangera and Brownell (2014) make a strong case that CUREs should be required for all life science students, and Ballen et al. (2017) describe broad benefits of involving nonmajors in CUREs. Besides helping students, enhancing the quality of undergraduate research programs has implications for improving the productivity and well-being of faculty, though organizing programs and securing faculty buy-in can present barriers (Healey et al., 2016). As animal sciences progresses toward greater inclusivity and more participatory undergraduate engagement, the quality of undergraduate research programs will play a central role in the functioning of the academic community.

Limitations and Future Directions

Our survey and scoping review represent an empirical deep dive into animal sciences teaching and learning topics since the ASAS centennial. Our research has at least six limitations. First, our survey assessed a small convenience sample of instructors across a limited timeframe. Our sample showed a distinct bias toward faculty with teaching appointments at research-focused doctoral universities and may not reflect the entirety of animal sciences faculty involved in teaching. Future work considering a larger, more random (or more purposive) sample of faculty across more diverse institution types may provide more generalizable insight. However, we also encourage research situated within specific subpopulations (e.g., faculty at junior colleges, administrators) to determine the particular needs and views of each group. Second, we constructed our own survey and relied on instructors to honestly self-report their perceptions. This approach is subject to investigator biases in survey construction and testing effects such as survey fatigue. Qualitative methods such as interviews or portfolio analysis may provide more valid data regarding instructor perceptions. Third, the results from our PCA—a purely mathematical, descriptive technique—are by no means intended as a comprehensive analysis of the structure and dimensionality of LO and CE. Such conclusions would require a larger sample size and accounting for the latent factor structure through factor analytic techniques (Kaplan, 2009). Fourth, our scoping review relied on provisional codes generated empirically through PCA. Although this approach minimized researcher bias in code generation, it does not capture important themes that might have emerged directly from the literature through qualitative analysis. Fifth, our scoping review summarized the volume of research on a large number of topics but did not address research on particular topics in-detail. We anticipate that future review papers will synthesize the research on much-needed topics as the volume of research in these areas increases. Finally, our creation and interpretation of research results is inextricable from our positionality and proximally influenced by our identification as animal scientists and instructors involved in research and teaching. None of our research team believes that any one LO or CE is best, rather, as Bourner (1997) suggests, that the best teaching methods and learning goals depend on the desired outcomes. However, unconscious biases such as familiarity may have influenced our analysis.

CONCLUSIONS

Our research empirically examined animal sciences teaching and learning topics since the ASAS centennial using an instructor survey and a scoping review of the literature. Instructor ratings showed that discipline-specific competencies and core experiential learning remained central to animal sciences' pedagogical identity. However, our results suggest emerging needs for internet-based and international learning opportunities. Our scoping review identified a gap in research assessing transferable skills driven by low quality and quantity of published research. Additionally, our results revealed needs for more research on community-integrated learning, global and research experiences, and internet-based learning. Ultimately, our results reinforce that developing scholarship of teaching and learning specific to our discipline is a requirement for teaching excellence and represents our greatest means for advancing animal sciences teaching to meet emerging challenges in the next century. Moving forward, we recommend that faculty, staff, and administrators work to:

- Use and document use of a greater variety of pedagogies, especially those online, international, integrated with the community, involving undergraduate research, and/or targeting transferable skills.
- Make specific transferable skills explicit in curriculum and incorporate rigorous, mixed-methods assessment.
- Partner with diverse experts both within and beyond animal sciences to catalyze knowledge-sharing across disciplines, institutions, and experiences.
- Develop situated theory and report on pedagogical content knowledge for emerging topic areas such as sustainability, data science, international agriculture, welfare science, and agricultural social science, among others.
- Define animal sciences' teaching and learning identity through a greater volume of interpretiv-

ist, theory-building work separating classroom, departmental, institutional, and discipline-based characteristics.

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