

Appendix 1

Expectations for an Exemplary Research Paper in Field Ecology Research and Teaching

Paper section	Expectations
Title	The title concisely conveys what the paper is about (e.g., objectives, research questions, focal taxa or ecosystem).
Abstract	The abstract consists of one paragraph of ≤ 250 words and clearly summarizes key components of the introduction, methods, results, and discussion.
Introduction	<ul style="list-style-type: none"> • Peer-reviewed sources of literature are used to provide background information on the topic and present a strong argument for conducting this study. Three appropriate references, cited in proper format, support statements. • Research objectives and questions are clearly stated and linked to each other.
Methods	<ul style="list-style-type: none"> • The study site description is clear and complete. • The study type, variables (independent, dependent), treatments, and number of replicates (if applicable) or sample size (if applicable) are clearly and completely described. The study design is appropriate for answering research questions. • Data collection and analysis methods are completely described in a clear step-by-step manner, and are appropriate for answering research questions.
Results	<ul style="list-style-type: none"> • Key results (including statistics) are clearly and accurately interpreted in the text. Research questions are answered. • Key results are summarized in tables or figures that are referenced properly in the text. Captions and axis labels are clear, complete, and concise.
Discussion	Ecological explanations are provided for all key results. Statements about the broader importance of results (e.g., how results can be applied in ecosystem management) are provided and supported by at least three properly-cited peer-reviewed references.
References	At least three appropriate peer-reviewed sources are properly cited and referenced in this document.
Writing	The paper is well organized. Proper grammar is used, spelling errors and repetitive statements are absent, the writing style is concise, and adjacent sentences and paragraphs are well-linked (good flow).

Appendix 2

Examples of Research Papers and Related Teaching Activities Completed in Field Ecology Research and Teaching and Standards Addressed

Research paper title	Related teaching activity title	NGSS addressed in teaching activity
Do constructed wetlands actually filter nutrient pollution from surface water?	Water quality and biodiversity in wetlands	K. Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment, ESS3.C: Human Impacts on Earth's Ecosystems
Sex ratios of painted turtles (<i>Chrysemys picta</i>) in local wetlands	Adaptations in aquatic and terrestrial turtles	1. Structure, Function, and Information Processing, LS1.A: Structure and Function
Effect of solar radiation intensity on grassland insect abundance and activity	Insects and seasons: adaptations for survival	1. Structure, Function, and Information Processing, LS1.B: Growth and Development of Organisms
A comparison of arthropod communities inhabiting milkweed (<i>Asclepias</i>) and goldenrod (<i>Solidago</i>)	A comparison of arthropod abundance and diversity in a tallgrass prairie and mown lawn	2. Interdependent Relationships in Ecosystems, LS4.D: Biodiversity and Humans
Abundance and taxon richness of soil-dwelling woodland invertebrates in relation to leaf litter abundance	Is leaf litter just "litter"?	2. Interdependent Relationships in Ecosystems, LS4.D: Biodiversity and Humans
The relationship between soil moisture and root biomass in a wet grassland ecosystem	Plant diversity change along a grassland hillslope	2. Interdependent Relationships in Ecosystems, LS4.D: Biodiversity and Humans

Note. First-grade students constituted the learner group in teaching activities. Additional information on completed research projects and teaching activities is available at the course website (<https://www.nrem.iastate.edu/fieldecology/>).

Appendix 3

Expectations for an Exemplary Teaching Lesson Plan in Field Ecology Research and Teaching

Lesson plan section	Expectations
Title	The title concisely communicates activity context (e.g., kinds of organisms, ecosystem) and what will be learned (central concept).
Introduction	The study topic and ecological context are clearly described. Central concepts taught are described in detail. Additional learning objectives (e.g., students will learn how to identify two species of plants) are clearly stated and achievable. Student characteristics (ages, education level, number of participants) and time requirements for each phase of the lesson are described.
Methods	
Study sites	Study sites appropriate for this lesson are clearly described (including classroom facilities that could be used, if applicable).
Materials	The description of required materials is clear and complete.
Preparation	Procedures needing to be completed before engaging the students are clearly and completely described.
Engagement	Methods of introducing the students to the activity are described, including a series of questions to assess knowledge about the subject and stimulate interest in the topic.
Exploration	Procedures that must be demonstrated to and followed by students are clearly and completely described. Procedures are connected to central concepts and other learning objectives.
Concept development	An effective set of questions and scientific terms are provided to help students assemble information obtained during the exploration phase, understand key findings, and learn central concepts. Answers to questions will help instructors assess student thinking.
Concept application	An effective set of questions is provided to help students understand ways that central concepts they have learned apply in other contexts, including applications to their own lives (i.e., the “take-home message”). Answers to questions will help instructors assess student learning.
Connections to Next Generation	Central concepts taught are aligned with one or more Next Generation Science Standards. A standard is listed, with a clear explanation of how the activity is aligned to this standard.

Science Standards	
References	At least three appropriate peer-reviewed sources are properly cited and referenced in the lesson plan.

Appendix 4

Photo of Student's Poster During Investigation



Note. A student attaches an arthropod model to a poster board during an investigation of the relationship between leaf litter abundance and diversity of soil-dwelling organisms in a woodland (Is leaf litter just “litter”?; Appendix 2). Models in the green box (right side of poster board) and red box (left side) represent numbers and kinds of arthropods collected from sampling plots with and without leaf litter, respectively. Students observed that biodiversity was greater in the plot with leaf litter, which apparently provided an essential habitat for some arthropod taxa.

Appendix 5

Examples of Student Grades

Research proposal	Research paper	Teaching lesson
Draft 1 = $87.3 \pm 1.9\%$	Draft 1 = $87.0 \pm 4.5\%$	Draft 1 = $83.0 \pm 6.6\%$
Final draft = $93.2 \pm 2.8\%$	Final draft = $93.7 \pm 2.6\%$	Draft 2 = $91.8 \pm 4.3\%$
		Final draft = $95.3 \pm 2.8\%$

Note. Grades are shown as mean \pm standard deviation for percentage of possible points earned for research proposals, research papers, and teaching lesson plans in the fall 2020 semester ($n = 12$ students). In each course offering to date, we have noted improvements in student work on later drafts, which reflects their learning related to both research and teaching.

Appendix 6

Student Responses to Questionnaire Before and After Completing Field Ecology Research and Teaching

Statement	Pre-course mean	Post-course mean
I know the meaning of the following terms:		
1. Experimental hypothesis	4.25	4.92
2. Independent variable	4.17	4.92
3. Dependent variable	4.17	4.92
4. P-value	3.17	4.17
I'm confident in my ability to:		
1. Design an ecological research project	3.33	4.58
2. Use valid data collection methods	3.83	4.58
3. Analyze research data	3.58	4.25
4. Write a research paper in scientific format	3.50	4.75
5. Write an abstract of a research paper	3.58	4.75
6. Assemble and cite research references	3.92	4.83
7. Collaborate with peers on a research project	4.00	4.92
I'm confident that I can:		
1. Design an ecology teaching activity	3.50	4.67
2. Guide K-12 students in collecting data	3.33	4.58
3. Guide students in answering questions about ecology	3.75	4.75
I have the skills and abilities to:		
1. Write a formal teaching lesson plan	3.25	4.58
2. Design teaching activities that will be engaging	3.42	4.92
3. Develop and pose effective questions	3.42	4.92
4. Teach K-12 students about ecology	3.42	4.67
5. Collaborate with peers on a teaching activity	4.08	4.92
I'm familiar with how to use:		
1. Next Generation Science Standards	2.83	4.75
2. Public presentation techniques	4.00	4.83
3. Skills in describing my research and teaching	3.42	4.83

Note. Student respondents' reported knowledge and skills related to research and teaching based on questionnaires administered before and after completing Field Ecology Research and Teaching in fall 2020 ($n = 12$ student responses for each question). Respondents used a 5-point scale (1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, 5 = strongly agree) for each question.