Advancing Undergraduate Field Experiences with Digital and Analog Data Collection Methods*: A Prairie Ecology Example*

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Abstract – The summer 2022 prairie ecology course at Iowa Lakeside Laboratory collaborated with the state ecologist to complete a botanical survey of a grazed native prairie in northwest Iowa. Data collection included the use of Esri Survey123 and a team-based approach to data collection. Long-term objectives of this field course are to prepare young field scientists with authentic learning experiences relative to existing and future careers in field science. This case includes lessons learned and potential next steps for training a new generation of grassland ecologists.

Introduction

Field science in the 21st Century retains many fundamental elements of basic scientific inquiry. However, the advent of digital devices and related technologies provide opportunities for budding field scientists to experiment with new methods of gathering data. In summer 2022, the prairie ecology course at Iowa Lakeside Laboratory partnered with the state ecologist to conduct a botanical survey comparing grazed and ungrazed tracts of a native prairie in northwest Iowa. Using a team-based approach and digital tools such as Esri Survey123 and plant identification apps, students engaged in authentic fieldwork that blended traditional methods with emerging technology. Guided by the Undergraduate Field Experiences Research Network (UFERN) model, this project fostered teamwork and hands-on learning while navigating challenges related to digital tools and sampling protocols. Anecdotal observations suggest light grazing favored or disfavored select species, though overall species richness remained similar between treatments, with quantitative results to be presented in a subsequent publication. These findings inform adaptive management decisions at Kirchner Prairie and position the site as a future testing ground for integrated data collection, analysis, and student training in field ecology. While traditional methods of field science retain core elements of basic scientific inquiry, this experiment enabled an integration of digital technologies for enhanced data collection methods and an innovative approach to initiate and sustain student engagement. By integrating mobile devices and applications into a systematic vegetative survey comparing grazed and ungrazed tracts of a native prairie, this project combined traditional techniques with commonly used devices to create a multifaceted learning environment. Through teamwork and reliance on familiar resources, students explored new potential dimensions of field science while making an authentic contribution to applied ecological management.

The study addressed the following questions:

1. How effective are mobile devices as tools for systematic vegetative surveys?
2. Can integrating personal mobile devices encourage future careers for field scientists?

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Historical vs current status of systematic botanical surveying as a method of place-based practice

For several decades, scholars have noted a shift in undergraduate education away from natural history-based experiences toward a greater emphasis on digital and laboratory-based sciences, thus diminishing opportunities for experiential learning in botany and field ecology (Wilcove & Eisner, 2000; Kramer, 2015). However, field-based inquiry remains vital, especially when addressing complex environmental issues. Place-based education frameworks encourage multisensory engagement, mentorship, and career development through immersive experiences (Fors et al., 2013; Sobel, 2004). At a time when understanding ecological systems is critical in the face of climate change and Anthropogenic impacts abound, there is an urgent need to recruit and inspire students to pursue careers in field-based science. Traditional field science often occurs as a solitary, analog process of data collection and interpretation. More technologically advanced sciences for coursework, majors and career choices have eclipsed natural history, botany and field research as career choices and majors over the past quarter century (Wilcove & Eisner, 2000; Woodland, 2007). Emphasis on STEM careers since the early 2000s coincided with generations of both parents and children hesitant to engage in outdoor experiences, opting instead for indoor experiences guided by devices, software and passive learning; resulting in an "extinction of experiences" relative to nature (Beery et al., 2023; Gaston & Soga, 2020; Louv, 2008). In recent years, "connectivity" in education has referred more to enabling high speed internet access for education and interpreting an inundation of digital data, rather than *re-connecting* humans and natural systems to address challenges related to climate change, resource scarcity, biodiversity and habitat loss (Pietrzak, 2017). Meanwhile, complex environmental problems persist and the need for future experts in field sciences grows ever more imperative.

Data scientists are necessary for solving contemporary problems, and their work must be complemented by experts who can contextualize the results of their analysis. Natural history remains the foundation for knowledge of systems and organisms found in nature, even as the information age expands the extent and dimensions of data available for study (Bartholomew, 1986; Boyd, 2006). For more than a century, ecologists, botanists and natural historians have expounded on the "endangered" condition of university programs and course offerings, giving weigh to subjects and material more rooted in digital platforms, device and molecular technologies, leading scholars to specialize in methodology and often overlook the very systems in which the subjects of study exist (Grant, 2000; Jordan, 1916; Kruckeberg, 1997; Peters, 1980; Schmidly, 2005). The result is fewer than half the federal workforce, to date, likely engaged in critical plant-based sciences but lacking basic botany skills necessary to fully understand or implement appropriate strategies (Kramer, 2015). Desktop data analysts can likely model biogeochemical conditions using state-of-the art digital tools but may not necessarily understand the context of their work in a real-world setting.

Emphasis on STEM-based skills in education often prioritize career choices and skills development for careers lacking field-based experiences. While the sciences may have shifted toward genetics, molecular extractions and other lab-based experiments related to organisms found in nature, social rhetoric continues to reinforce the human connection to place, single species and ecosystems as a means of management, protection and preservation (Dodinet, 2016; King & Achiam, 2017). A student's connection to place serves as a foundation for not only basic education, but also in a manner that can foster a positive, formative, mentor-led multisensory experience (Fors et al., 2013; Powell, 2010; Sobel, 2004; Vander Ark et al., 2020). STEM-based education has the capacity for including field sciences in a way that also incorporates the use of modern technologies. However, if students are reluctant to spend time outdoors, such experiences prove challenging.

While Thoreau, Muir and Leopold may have extolled the virtues of time spent in nature as a balm for societal maladies, today's experience may be looked upon less fondly by a more digitally focused youth. When subjected to unfamiliar places and spaces, young people today may not embrace the opportunity with the same zeal for nature and the outdoors as their predecessors. Research on the societal impacts of the CoVID-19 pandemic also suggest young people experience a heightened sense of anxiety with greater fear of uncertainty and are inherently more risk averse (Cerbara et al., 2020; Gewalt et al., 2022; Nadareishvili et al., 2022; Scerri et al., 2020; Xie et al., 2020). Instead of a source of solace and relaxation, an outdoor experience for some young people can be riddled with anxiety, fear, and concern for personal safety due to the lack of familiar and comfortable conditions they may associate with work indoors.

A relatively low-risk opportunity to re-associate nature and field-based learning can occur at the undergraduate level for today's students due to the short-term nature of course activities, as well as emphasis on methodology, skill building and appropriate techniques in the sciences. Outcomes of undergraduate field experiences are a function of each student's perspective, resulting from the interface of personal identity and the structure and process of the experience itself (Hodder, 2009; O'Connell, Hoke, Giamellaro, et al., 2021). Students are able to gain not only a fundamental knowledge of ecological and scientific principles, but also a broad understanding of practical application and career development through hands-on learning. This includes opportunities not traditionally available to underserved communities (Riggs, 2005). Biological field stations, marine laboratories, and geoscience field camps provide myriad opportunities for student engagement, mentorship and early career development for the undergraduate (O'Connell, Hoke, Berkowitz, et al., 2021). This unique combination of student-focused activities provides an opportunity to overcome a portion of anxieties and uncertainties associated with field-based scientific research.

Beginning in 2020, Iowa Lakeside Laboratory engaged with the Undergraduate Field Experiences Research Network (UFERN) through a series of workshops designed to support collaboration among field stations, marine labs, and STEM research teams focused on immersive outdoor learning (www.ufern.net). This partnership led to the intentional incorporation of the UFERN model into faculty development and course design for the 2021 and 2022 IALL:3034 Prairie Ecology summer field courses at Iowa Lakeside Laboratory Regents Resource Center, located in northwestern Iowa. The UFERN framework highlights the interplay between student perspectives and the structure of field-based programs, emphasizing how worldviews, a sense of scientific belonging, and student empowerment shape learning outcomes. By grounding its pedagogy in this model, the prairie ecology course fostered mentorship, skill-building, and project ownership through collaboration with technical experts and use of digital tools. These experiences supported students in developing technical confidence, a strong sense of identity as scientists, and the self-authorship necessary for sustained engagement in field-based science careers. The UFERN model approach extends from a structured undergraduate research experience where collaboration with technical experts, skills development and a sense of project ownership lead not only to a sense of technical confidence and personal identity, but also an *enculturation* of scientific expertise and self-authorship as fundamental outcomes (Auchincloss et al., 2014). This framework provides guiding principles for general field-based education at the undergraduate level and also serve as the foundation for methods applied as part of this project.

Materials & Methods

Study Area; Kirchner Prairie

Located in rural Clay County, Iowa, Kirchner Prairie is a remnant prairie pasture comprised of a diverse vascular plant community. A 2012 species inventory recorded 158 unique vascular plant species, followed by a biennial systematic inventory, documenting 155 unique species (Rosburg, 2013). The site is actively grazed, with physical exclosures. The site is approximately 20 miles from Iowa Lakeside Laboratory and has been included in field excursions for the IALL:3123/3125 Prairie Ecology field course since 2021. See Figure 1. The field study site is located approximately 20 miles southeast of the Iowa Lakeside Laboratory campus in rural Spencer, Iowa.

Methodology

The UFERN pedagogical model played a central role in shaping the structure, design, and delivery modalities of the Prairie Ecology course (IALL:3034/3123), beginning in 2022.The UFERN framework emphasizes the interplay between student identity, program structure, mentorship, and self-authorship as guiding principles for undergraduate field

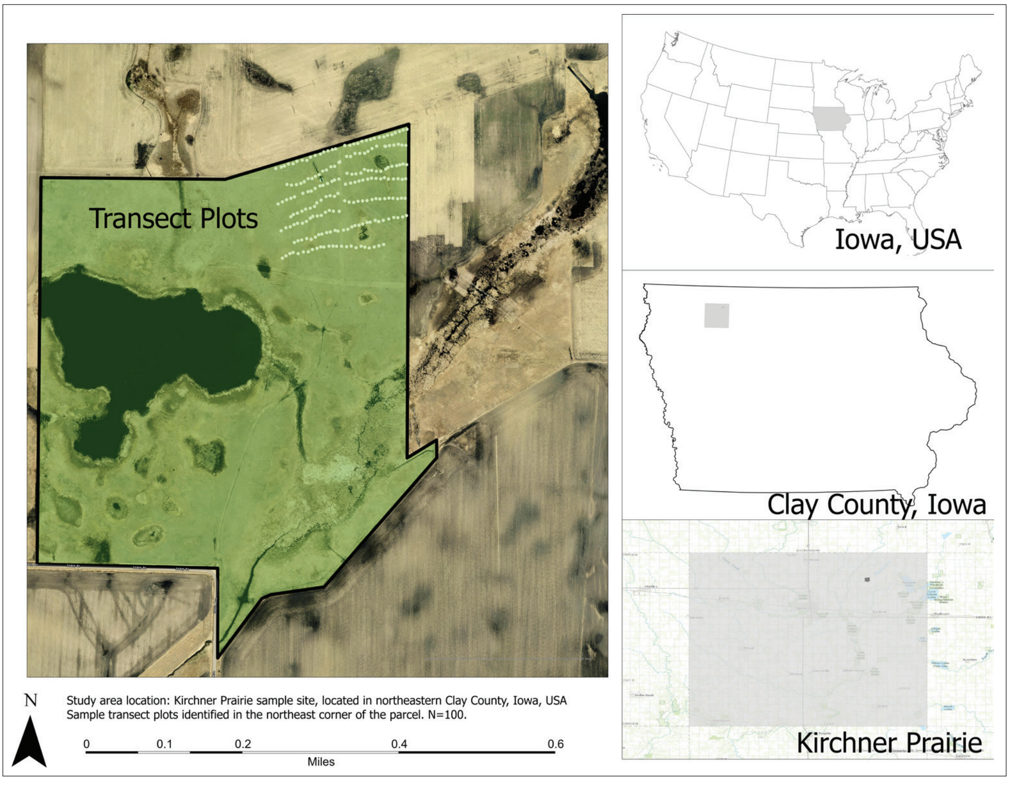

Figure 1. Location of Kirchner Prairie, within the Dan Green Slough Wildlife Management Area (WMA) in northeastern Clay County, Iowa. Transect sampling locations are identified as yellow points within the northeast quadrant of the parcel. N=100.

experiences. Within this context, the Prairie Ecology course was designed to provide students with authentic, hands-on opportunities to conduct fieldwork in collaboration with practitioners and content experts, including the State Ecologist. By situating the Kirchner Prairie survey within the UFERN framework, the course aligned skill-building and technical training with mentorship and teamwork, thereby supporting both ecological data collection and professional development outcomes for students. Table 1 summarizes pedagogical dimensions and application of UFERN principles to the Prairie Ecology field experience as a structured lens for evaluating both student learning outcomes and ecological results.

In 2022, Kirchner Prairie was included as a two-day field experience for students to engage in a systematic plant survey of the site, led by State Ecologist, Dr. John Pearson. Students were equipped with an Esri® ArcGIS Online Survey123™ form, accessible by their mobile phones, to capture species names, geographic locations and qualitative assessments

Table 1. Application of UFERN Dimensions in IALL:3034/3123 Course Activities derived from the UFERN = Undergraduate Field Experiences Research Network.

UFERN Dimension	Application in IALL:3034/3123 Course	Observed/Anticipated Outcomes
Student Identity & Belonging	Students worked in collaborative teams during the Kirchner Prairie survey; roles rotated among digital data entry, scribe, and plant identification.	Enhanced sense of ownership and belonging; students reported confidence in contributing to authentic field science.
Mentorship & Community	Daily interaction with State Ecologist and course instructor; peer mentoring as experienced students guided newcomers.	Strengthened scientific community ties; two students later pursued field-based ecological work citing this project as formative.
Structure of Experience	Two-day intensive survey of grazed vs. ungrazed plots using both Survey123 (digital) and notebooks (analog).	Established repeatable methodology; reinforced systematic practice while comparing efficiency of digital vs. analog tools.
Skill-Building & Technical Confidence	Training in Survey123 offline mode, botanical identification, and redundancy between analog/digital notes.	Increased technical resilience; students gained confidence in troubleshooting technology and handling field constraints (connectivity, battery).
Self-Authorship & Agency	Students developed process refinements on Day Two; adjusted team workflow and data-entry sequence.	Greater student agency in field decisions; demonstrated adaptability and problem-solving in real-world conditions.
Reflection & Career Development	Informal debriefs after field days; future iterations planned to include structured reflection tools.	Preliminary outcomes suggest stronger interest in ecological careers; reflective practice expected to enhance long-term impact.

of abundance within a total of 200 one-square meter plots arranged in linear transects. Half of the transects were located within the ungrazed exclosure area and the remaining transects were within the actively grazed portion of the site.

The Survey123 form was used by four team members to record species names and cover levels (1: low, 2: moderate, 3: high) as indicated by Pearson. One student served as a project scribe, documenting the species list and abundance scale for each transect in a field notebook. While statistical analysis and additional quantitative metrics will be explored in a subsequent paper focused specifically on comparative ecological outcomes, the present study emphasizes the integration of digital tools with field-based learning methods.

For all, including our State Ecologist, this was a new experience and opportunity for learning. With limited outdoor activities included in previous coursework for nearly all students involved, and none directly pertaining to activities commonly conducted by professional field scientists, the entire class were beginners at any form of systematic surveying. Methods in use by the students were also a deviation from traditional methods among existing practitioners. By collecting both analog and digital records from the 100 plots in both grazed and ungrazed areas of the parcel, students were able to generate a redundant dataset for quality assurance purposes, and also immediately generate a dataset for further quantitative analysis.

Students used a mobile application to collect data offline, which automatically uploaded as soon as they returned to campus and connected to a strong Wi-Fi signal. Hard copy records were then referenced when reviewing and editing data prior to any quantitative analysis. Notes were recorded in both digital and analog formats to document any errors that needed correction after data collection. The authors collaborated on final data revisions, which took place later in the year.

Results

The first day of data collection spanned a total of more than nine hours in the field. Day one required both general orientation to the sampling process, as well as gaining a sense of comfort and flow with the data entry process. By establishing a routine to the process, including sequential data entry and familiarization with the tools, the second day was a six-hour duration. Three students participated in digital data entry on Day One, and five assisted with Day Two data entry, also likely contributing to the reduced duration. Once the team returned to the Iowa Lakeside Laboratory campus and regained network connectivity, all data were submitted.

The students recorded 2,162 unique records of plant species identified during the two-day survey July 28 and 29 at the field site. Rapid data analytics generated from Survey123 identified a total of 1,085 records of species occurrence (50.19%) in the actively grazed transect, with 1,077 individual species occurrences in the protected exclosure (49.81%). Using the general classification system within the Survey123 field form, species cover was predominantly moderate for 1,068 or 49.4 percent of all plants identified. Anecdotal interpretation of the data indicate low cover for 864 individual species occurrences, or 39.6 percent of all occurrences identified, and 230 occurrences identified were classified as having high cover, at 10.64 percent of all occurrences identified. Together with frequency data, these observations serve as the foundation for further analysis and interpretation, which is planned fora subsequent paper.

Overall, a total of 106 species were recorded from the 200 quadrats spread across the two combined tracts, with 94 species in the ungrazed exclosure and 79 species in the grazed pasture. The species most frequently encountered were smooth brome (*Bromus inermis*, 68 quadrats in the grazed tract), big bluestem (*Andropogon gerardii*, 55 quadrats in the ungrazed tract), and golden alexanders (*Zizia aurea*, 53 quadrats in both the grazed and ungrazed tracts). Many species were recorded in only single quadrats per tract: 17 in the ungrazed tract and

15 in the grazed tract; examples are common milkweed (*Asclepias syriaca*), wild flax (*Linum sulcatum*), and prairie turnip (*Pediomelum esculentum*). Species occurring in only a few quadrats were not useful in discerning contrasts in dominant vegetation between grazed versus ungrazed tracts, so only the most frequent 15 species in each tract (occurring in 25 or more quadrats in at least one of the tracts) were utilized in the following analysis (see Table 2).

Preliminary inspection of results indicated that the ungrazed tract exhibited a greater frequency of six species: big bluestem, gray-headed coneflower, yellow loosestrife, Kentucky bluegrass, Virginia mountain mint, and smooth blue aster. The grazed tract had a greater frequency of nine species: porcupine grass, purple meadow-rue, panic-grass, redtop, cream indigo, smooth brome, wild rose, prairie coreopsis, and rattlesnake master. Three species – golden alexanders, western sunflower, and Missouri goldenrod – showed little or no difference in frequency between the grazed and ungrazed tracts. Among native species, six species were more frequent in the ungrazed tract while seven were more frequent in the grazed tract. Among non-native species, one – Kentucky bluegrass – was more frequent in the ungrazed tract while two – redtop and smooth brome – were more frequent in the grazed tract. Shifts of frequency among native species illustrate their adaptability to a range of grazed and ungrazed conditions and are viewed by natural resource managers as a benign outcome.

Table 2. Frequency (%) of the 15 most common species observed in grazed and ungrazed prairie plots.
Presence, U = Ungrazed; G = Grazed.

Common name	Scientific name	Presence	Ungrazed	Grazed
Big bluestem	*Andropogon gerardii*	U, G	55	45
Golden alexanders	*Zizia aurea*	U, G	53	53
Gray-headed coneflower	*Ratibida pinnata*	U, G	43	26
Porcupine grass	*Stipa spartea*	U, G	38	46
Purple meadow-rue	*Thalictrum dasycarpum*	U, G	38	45
Yellow loosestrife	*Lysimachia quadriflora*	U	37	6
Panic grass	*Dichanthelium spp.*	U, G	36	48
Redtop	*Agrostis gigantea*	U, G	34	44
Kentucky bluegrass	*Poa pratensis*	U, G	34	25
Virginia mountain mint	*Pycnanthemum virginianum*	U	34	14
Cream indigo	*Baptisia bracteata*	U, G	31	43
Western sunflower	*Helianthus rigidus*	U, G	30	27
Smooth blue aster	*Symphyotrichum laeve*	U	29	18
Missouri goldenrod	*Solidago missouriensis*	U, G	27	25
Smooth brome	*Bromus inermis*	U, G	26	68
Wild rose	*Rosa spp.*	G	26	38
Prairie coreopsis	*Coreopsis palmata*	G	14	36
Rattlesnake master	*Eryngium yuccifolium*	G	6	28

However, apparent increases in the frequency of non-native species in the grazed tract is concerning to managers wishing to utilize grazing as a management tool while maintaining the prairie in a predominantly native condition. Additional study is underway to further evaluate this outcome, including consideration of alternative grazing regimes that do not facilitate increases of non-native species.

Discussion

The following details highlight key aspects of the UFERN model as it relates to the field work and student experiences incorporated with this project. Generally speaking, students gained an authentic, hands-on experience with a professional mentor in the field; they gained insight to customary field science methods and procedures related to systematic sampling in prairies; and they learned first-hand the conditions under which such work takes place, growing credibility and understanding of the rigor associated with field science and ecology.

Mentorship benefits

During this exercise, students interacted with experts who use science to monitor and improve management of natural resources. Quick digital summary of data shortly after finishing a day's field work enabled managers to share identification of positive and negative implications of the results, in turn providing students with the gratification that their effort truly contributed toward a meaningful follow-up.

Methodological and Technical Lessons

Upon submission of the species identified in the hundredth plot of the actively grazed transects, data were immediately available for analysis in tabular form, saving hours of manual data entry which would normally occur after two full days of field work. Survey123 generated initial summary statistics, categorical summaries, and eliminated a time-consuming step of data entry typical with field survey work of this kind.

Survey123 facilitated data entry and preliminary analysis, eliminating transcription errors and streamlining the field-to-database process. However, connectivity issues and battery drain were limitations. Offline mode and backup power sources were necessary. Compared to analog-only methods, Survey123 increased data collection efficiency but required up-front training and troubleshooting. Should field assistants have adequately charged devices and secondary power supplies, and download applications for offline use, these challenges can likely be averted in future applications.

Student Preparedness and Resilience in the Field

As a relatively remote location in rural Iowa, data connectivity was sporadic. Students who had not downloaded the full application for offline usage were unable to successfully implement the tool. Furthermore, students not entirely comfortable with long hours in the field experienced discomfort. One student experiencing distress left the field site and returned to the vehicle for over an hour during the first morning of data collection. Conversely, the team of data collectors expanded on the second day to include other students from the field station who had expressed interest in learning about the process and experiencing a systematic field survey. Team-based discussions regarding efficiencies in data collection refining the process and enabling equal opportunities for experience were part of the first day's exercise. By Day Two, and with the addition of two new participants, the process was refined and completed with added enthusiasm for the project. The manual data scribe remained the same for both days to ensure consistency, and the rest of the team rotated a sequence of entering single-species data into the Survey123 form. The UFERN framework shaped course design by emphasizing team-based inquiry, mentorship, and student agency. While formal assessment was not conducted, anecdotal observations indicate increased confidence and curiosity. At the time of publication two students who participated in the project have since pursued careers in field-based ecological work and credit this experience as a formative influence. Future iterations of this project will incorporate reflection tools to better evaluate short- and longer-term outcomes.

A new site survey was planned for 2024, once again involving student participation and the use of the Survey123 form, allowing for direct comparison of these results with previous assessments conducted by both Pearson and Rosburg. The form will be revised to align more succinctly with preferred field methods identified by Pearson. Technological requirements will ensure all students are capable of operating the tool in a remote area with ample battery capacity.

For students considering field science careers, yet lack fundamental coursework in natural sciences, field botany and survey methods, such an activity can provide an initial opportunity to determine whether or not the experience is one worthy of further pursuit. For some, the experience may be too tedious and physically strenuous, while for others it may be an inspiration leading to a career of field-based science. In addition to immediate gains in confidence and technical competence, several students from this and previous years of the Prairie Ecology course have translated their field experiences into concrete career opportunities. Alumni have gone on to serve as technicians at the Iowa DNR Prairie Resource Center, wildlife management unit interns, seasonal field assistants with The Nature Conservancy, and staff members for County Conservation Boards. In each case, students reported that the course provided foundational skills in plant identification, ecological sampling, and the integration of modern digital tools such as Survey123. These outcomes underscore the role of the field course not only as an academic exercise but also as a formative professional stepping stone, consistent with UFERN's emphasis on identity formation, agency, and career persistence in ecological sciences.

Conclusion

The basic fundamentals of inquiry, research and data collection remain constant elements of science regardless of the tools, technology and skills applied in the field or elsewhere. An analog approach to knowledge will always be under threat as technology continues to evolve to solve global problems. Teachers and mentors are remiss to ignore and or eliminate the opportunities to integrate technology with traditional methods. At a minimum, such an approach may alleviate discomfort for students, and may possibly enable innovation by a younger technophile that older generations may not even consider. The key is to strike a balance between data integrity and the convenience of technological solutions. The evident career paths of course participants into positions with state agencies, conservation nonprofits, and local land management entities further demonstrate the value of this approach to learning as both a pedagogical model and a professional training ground for future prairie ecologists. Blending traditional botanical survey methods with digital tools like Survey123 enabled undergraduate students to contribute meaningfully to ecological research while gaining practical field experience. This hybrid approach, grounded in the

UFERN model, supported both ecological insight and pedagogical goals. These field-based observations of species-specific grazing responses and cattle movement patterns illustrate how student learning activities can simultaneously generate insights of practical value for adaptive prairie management. Future work will refine the survey form, explore additional metrics, and implement student feedback to enhance learning.

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Figure 2. Undergraduate students and collaborators at Kirchner Prairie, celebrating completion of the botanical survey. (photo by R. Kauten).

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