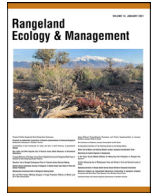




Contents lists available at ScienceDirect

Rangeland Ecology & Management

journal homepage: www.elsevier.com/locate/rama

Original Research

Exploring the Most Effective Form of Multimethod Rangeland Literacy Learning in Texas[☆]Erika Sullivan¹, Sakina Dixon², Morgan L. Treadwell^{3,*}¹ Rangeland, Wildlife, and Fisheries Management, Texas A&M University, College Station, TX 77845, USA² Ecology and Conservation Biology Department, Texas A&M University, College Station, TX 77845, USA³ Rangeland, Wildlife, and Fisheries Department, Texas A&M AgriLife Extension Service, San Angelo, TX 76901, USA

ARTICLE INFO

Article history:

Received 26 September 2024

Revised 27 January 2025

Accepted 16 June 2025

Keywords:

Grassland

Prescribed fire

Ranch tour

Rangeland

Web-based learning

Woody plant encroachment

ABSTRACT

Creating agents of change equipped with the knowledge of best management practices is crucial to the preservation of vulnerable grassland savannas facing woody plant encroachment. The goal of this study was to utilize a pre-post intervention design to determine the knowledge and attitude change associated with various outreach and education online, in-person, and hybrid approaches in adult and youth participants on rangeland literacy and woody plant management strategies, such as prescribed fire, multispecies grazing, and pyric herbivory. Key findings revealed that teaching methods that used web-based and blended learning modalities were most effective at improving knowledge and attitudes of participants. Additionally, we identified that 9th–12th age groups reaped the most benefits from fully web-based and blended learning approaches.

© 2025 The Authors. Published by Elsevier Inc. on behalf of The Society for Range Management.

This is an open access article under the CC BY-NC-ND license

<http://creativecommons.org/licenses/by-nc-nd/4.0/>

Introduction

The Great Plains of North America, recently identified as one of the 238 most biologically significant places in the world, is rapidly degrading due to woody plant encroachment (WPE) (Symstad and Leis 2017). Severe impacts from WPE have only been noted in few other regions outside the Southern Great Plains (SGP) (Wilcox et al. 2018). Historically, the plant communities in the SGP were open savanna, with limited populations of broadleaf evergreen and deciduous trees (TR) scattered among midheight C4 grasses (Liao et al. 2006; Wilcox et al. 2018). These ecosystems were maintained by both fire and herbivory until European settlement introduced large herds of domestic livestock (Van Auken 2000; Wilcox et al. 2018). Unlike the historic bison, these livestock were constrained, often in high numbers, resulting in landscape degradation to bare rock and mineral soil (Wilcox et al. 2018). This process eventually led to the elimination of fire, and the proliferation of opportunistic native species such as Ashe juniper (*Juniperus ashei* Buchh.), Eastern

redcedar (*Juniperus virginiana* L.), and the resprouting Redberry juniper (*Juniperus pinchotii* Sudw.) (Twidwell et al. 2013; Van Auken 2000). Much of the SGP, particularly Texas, is now dominated by TR and shrubs (SHR), with intact grasslands disappearing and existing primarily as pockets (Wilcox et al. 2018).

According to Twidwell et al. (2015), fire has been consistently recognized as an indispensable management tool for ensuring the continuity of fire-dependent ecosystem services. Prescribed fire, or the intentional controlled application of fire to meet landowner objectives, offers a cost-effective solution to prevent seedling recruitment and sapling maturation in mature woody TR (Hoffmann et al., 1999; Su et al. 2015). In addition, emerging research on multispecies and patch-burn grazing indicates that these management strategies are effective at reducing WPE, increasing forage quality, and increasing plant heterogeneity (Taylor 2008; Wilcox et al. 2018). Using these management strategies together mimics historic fire and herbivory regimes that once kept woody plants in low densities. Although these rangeland techniques are essential for rangeland sustainability, prescribed fire has not been widely adopted by private landowners (Harr et al. 2014). Additionally, the lack of awareness or knowledge of prescribed fire serves as a significant barrier then establishing education and outreach programs can be a solution. A study by Toombs et al. (2017) highlights how landowners with increased awareness of prescribed fire's ecological and economic benefits are more likely to implement it on their

[☆] This work was supported by the by USDA-NIFA program in Sustainable Agricultural Systems, Grant Number 12726253 "Enhancing Livestock Production in the Great Plains."

* Correspondence: Morgan L. Treadwell, Texas A&M AgriLife Extension and Research Center, 7887 US HWY 87 North, San Angelo, TX 76901, USA.

E-mail address: morgan.treadwell@ag.tamu.edu (M.L. Treadwell).

properties. And Kreuter et al. (2008) found that workshops and community-based programs enhance acceptance of prescribed fire by building trust and sharing best practices. By addressing the root cause of hesitancy—lack of knowledge and awareness—education and outreach can serve as effective strategies for encouraging the adoption of prescribed fire as a sustainable land management practice.

To overcome barriers limiting the widespread adoption of prescribed fire, multispecies grazing, and patch-burn grazing, multiuniversities, biome-scaled, research endeavors such as *The Prairie Project* (2020) (TPP—www.theprairieproject.org) have been developed. One of the main objectives of TPP is to establish education and outreach programs aimed at effectively building and enhancing rangeland literacy for current and future land managers, natural resource professionals, and the public. Enhanced rangeland literacy may lead individuals to adopt and implement the most effective strategies in WPE management. Furthermore, TPP has established partnerships with demonstration ranches across the Great Plains that are used as training facilities and to assess the practicality and effectiveness of patch-burn grazing, prescribed fire, and multispecies grazing. Additionally, TPP formed teacher/faculty cohorts and 4H/FFA cohorts to create agents of change and develop impactful public education materials concerning WPE and underutilized rangeland management strategies. To implement high-impact programs, TPP employs a combination of experiential and active learning strategies to improve the persistence and performance of students.

Using constructivist learning theory as a guide, we intend to examine the effectiveness of various teaching methods among students, educators, and young ranchers in Texas. These methods included hands-on learning, ranch tours, face-to-face traditional lectures, collaborative group-based learning, and web-based activities. Furthermore, pretest-post-test designs are frequently employed in behavioral research, mainly to assess changes resulting from experimental interventions (Dimitrov and Rumrill 2003). Therefore, we applied a quasi-experimental, sometimes called pre-post intervention, design to answer two research questions which are: 1) What is the knowledge change associated with each form of outreach and education in adult and youth participants on prescribed fire, multispecies grazing, and pyric herbivory? 2) How does each form of outreach and education influence attitude changes among adult and youth participants regarding prescribed fire, multispecies grazing, and pyric herbivory? Based on peer-reviewed articles used for background and literature review of this study, we developed two hypotheses: 1) Live demonstration and personal experience are the most effective methods for improving rangeland literacy and attitudes among participants and 2) K-12 participants will experience the most significant knowledge and attitude transformation.

Methods

Curriculum

Curriculum was created that utilizes the Rangeland Analysis Platform (RAP) to assess the impacts of prescribed fire, patch-burn grazing, and multispecies grazing on four cover categories: perennial forb and grass (PFG), SHR, TR, and bare ground (BG) (Sullivan et al. 2023). To create the teaching curriculum, individual shapefiles were made for four demonstration ranches and uploaded into RAP, and utilized by curriculum participants. The (RAP) is a free, online tool that provides data-driven insights into rangeland vegetation trends across the western United States. It utilizes satellite imagery and machine learning to deliver detailed, interactive maps and metrics related to vegetation cover, productivity and changes over time (Matzke et al. 2023). Both RAP and ground-reference data were used for these comparisons. A copy of the curriculum

used can be found at: <https://www.theprairieproject.org/resources/factsheets>.

Shapefiles included individual pasture names and treatments consisting of prescribed fire, livestock grazing, or both. The curriculum consisted of four parts. For part one, participants collected and compared data on pasture with fire vs. no fire or fire greater than 5 years old. Part two, participants collected and compared data on pastures with fire + livestock vs. single livestock species (cattle) only. Part three, participants collected and compared data on multispecies grazing vs. single-species grazing-only pastures. Part four, participants collected and compared data on grassland ecological sites vs. juniper-woodland ecological sites on the ranch.

In addition to the RAP, participants conducted rangeland monitoring on the same four demonstration ranches near San Angelo, TX using ground-truthing transects to determine vegetative cover. During rangeland monitoring, participants compared the on-the-ground data to data generated by the RAP within the curriculum discussing implications in WPE management and adoption. The two ground-truthing techniques that were utilized were: line-point intercept and closest individual methods. Ground cover categories consisted of grasses, SHR, forbs, TR, BG, rock, and litter. Closest individual method were taken at four random points along an established transect to evaluate the relative amount of TR present at the demonstration ranch sites.

Lastly, a traditional curriculum was created which consisted of a face-to-face lecture, an interactive walk-in rangeland activity, and a social media activity. The goal of the traditional curriculum was to build a fundamental understanding of rangelands, WPE, and rangeland stewardship using patch-burn grazing, multispecies grazing, and prescribed fire on Texas rangelands and throughout the SGP.

For the 2-year study, over 300 participants consisted of Texas A&M AgriLife County Extension Agents, Texas high school Agriculture Education science teachers, undergraduate college students, Texas Master Naturalists, Texas Section Society Range Management Youth Range Workshop, Ranch Brigades, and 4H/FFA clubs and chapters. Each group was assigned a curriculum teaching strategy and the same evaluation instrument was used across all participants, groups, and teaching strategies.

Survey instrument

A comprehensive question survey was crafted to evaluate the 1) knowledge change associated with hands-on learning, ranch tours, face-to-face traditional lectures, collaborative group-based learning, and web-based activities and 2) attitude change associated with these same learning approaches (Table 1). To determine which form of outreach and education correlated with positive knowledge and attitude changes anonymous surveys were administered immediately before and following the extension activity. This survey was approved by Texas A&M University's Institutional Review Board (IRB2023-0158).

RAP Curriculum workshop treatment

Twelve RAP Curriculum (only) workshops from 2022 to 2023 were conducted with 177 participants. These workshops took place at multiple locations across the state (Fig. 1). Each workshop included an introductory tutorial on the RAP Curriculum. Participants were tasked with completing the RAP Curriculum through self-paced web-based learning. The workshop concluded with a classroom discussion involving participants and facilitator, where participants shared their findings and discussed the implications of using prescribed fire, multispecies grazing, and patch-burn grazing as management tools. Duration of the RAP Curriculum workshops varied, spanning anywhere from 1 to 6 hours. The time frame was

Table 1

Survey evaluation questions comparing knowledge and attitude change associated with various outreach and education online, in-person, and hybrid approaches in adult and youth participants on rangeland literacy and woody plant management strategies using fire and grazing.

Rangeland literacy	Woody plant encroachment
1. I have a clear understanding of what a rangeland it.	1. There are benefits to using goats, in addition to cattle, for managing rangelands against woody plant encroachment.
2. Which of the following is/are natural features of rangelands? 1) Fire, 2) grazing, 3) both fire and grazing, 4) neither fire or grazing.	2. I am familiar with the Rangeland Analysis Platform (RAP).
3. _ eat more grasses and _ eat more leaves and twigs of shrubs and small trees. 1) Cows ... goats and 2) goats ... cows.	3. Which of the following are essential to sustaining rangelands from woody plant encroachment? 1) Fire, 2) grazing, 3) both fire and grazing, 4) neither fire nor grazing.
4. Which of the following are considered rangelands (select all that apply)? 1) Prairie, 2) forest, 3) savanna, 4) shrubland, 5) meadow.	4. I have heard of the Rangeland Analysis Platform.
	5. I have used the Rangeland Analysis Platform before.

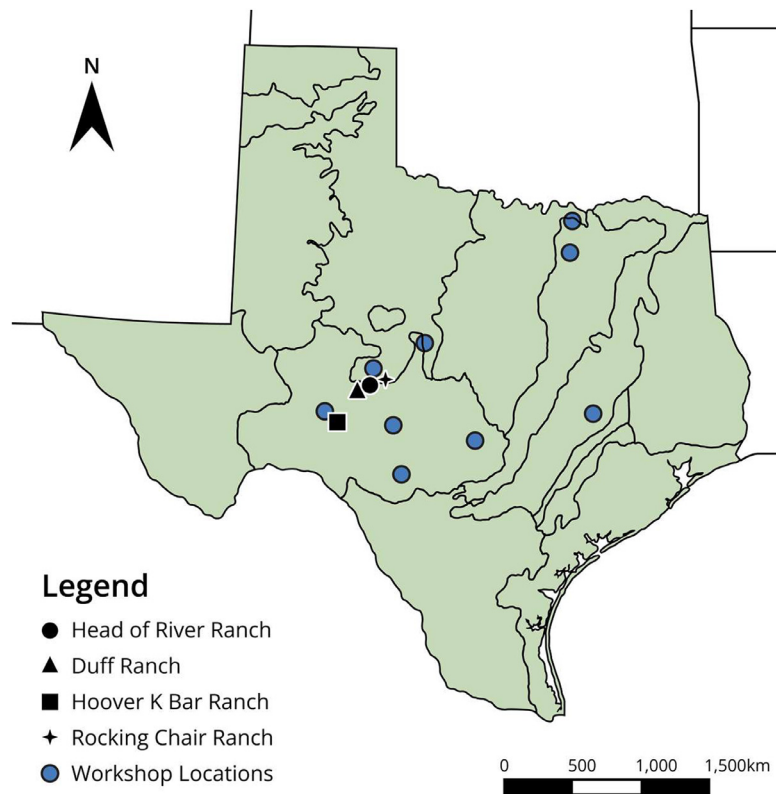


Figure 1. Approximate locations of participating Prairie Project demonstration ranches and workshop locations for all age groups in Texas.

dependent on factors such as the workshop's participant count and the duration participants took to complete RAP Curriculum.

RAP Curriculum + Ranch Tour workshop treatment

The RAP Curriculum + Ranch Tour workshop treatment adhered to a similar guideline as the RAP Curriculum workshop treatment, recruiting 17 participants. During the ranch tour, participants were divided into groups and completed a ground-truthing exercise utilizing the line-intercept and closest-individual methods. After ground-truthing each burned and grazed pasture, participants engaged in dynamic group-discussions with the owner/operator of the demonstration ranch regarding implications of using prescribed fire, multispecies grazing, and patch-burn grazing as management tools. Additionally, participants conducted a comparison of RAP data that was previously generated from the same ranch pastures with their on-the-ground data collected.

Ranch Tour workshop treatment

Between 2022 and 2023, a total of five ranch tours were organized with 28 participants (Fig. 1). Each tour began with an intro-

duction and a discussion with the owner/operator regarding management strategies used on the respective demonstration ranch. To facilitate the hands-on experience, participants were divided into groups and completed the ground-truthing exercise utilizing the line-intercept and closest-individual methods. Notably, the ranch tours featured visits to three to four pastures, which corresponded to those pastures highlighted in the RAP Curriculum. After ground-truthing was completed, participants engaged in detailed and lively group discussions with the rancher that delved into the implications of using prescribed fire, multispecies grazing, and patch-burn grazing as effective land management tools. Additionally, participants compared RAP data with on-the-ground data they collected from earlier that day.

RAP Curriculum + Ground Truthing workshop treatment

Between 2022 and 2023, a total of four workshops were organized for the RAP Curriculum + Ground Truthing treatment group with 115 participants (Fig. 1). The RAP Curriculum + Ground Truthing workshops followed the same guideline as the RAP Curriculum workshops. However, participants conducted the ground-

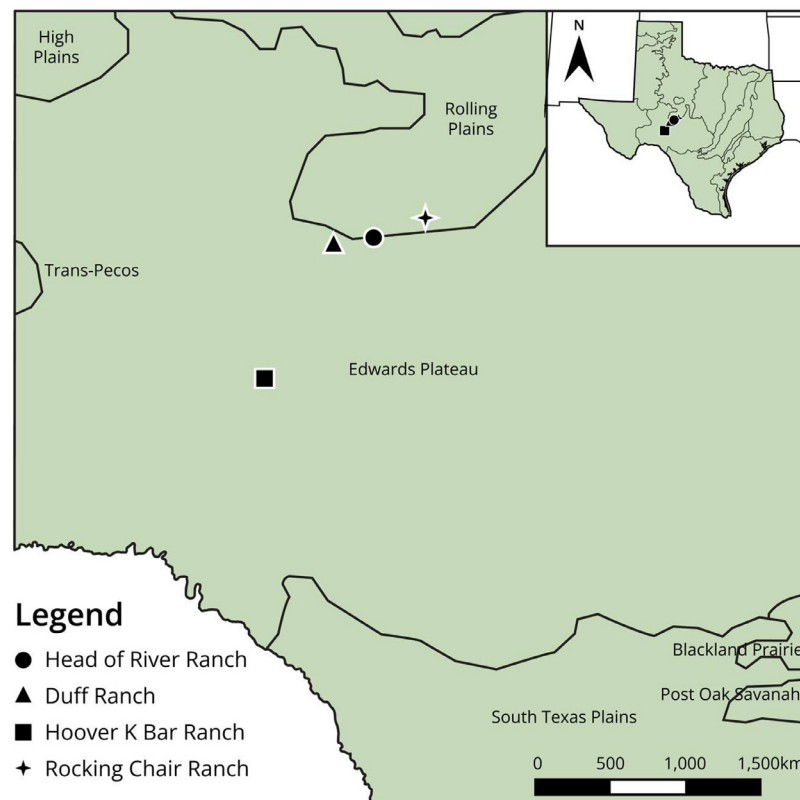


Figure 2. Approximate locations of participating Prairie Project demonstration ranches.

truthing exercise in an adjacent rangeland area instead of a designated Prairie Project demonstration ranch. Following the ground-truthing activity, participants engaged in dynamic group discussions pertaining to the implications of utilizing prescribed fire, multispecies grazing, and patch-burn grazing as effective land management techniques. Furthermore, participants were asked to compare their collected RAP data with the actual on-the-ground data.

Study sites

TPP is partnered with four demonstration ranches in Texas: Head of the River Ranch, Rocking Chair Ranch, Duff Ranch, and Hoover K. Bar Ranch (Fig. 2). These ranches are in Crockett, Tom Green, and Schleicher Counties all encompass a diverse geographical region in the Edward's Plateau and Rolling Plains Ecoregion. Annual rainfall in the Edward's Plateau ranges from 15 to 34 in (Texas Ecoregions—Texas Parks & Wildlife Department 2022). Soils in this region are shallow and underlain by limestone, and the main vegetation types are grasslands, juniper-oak woodland, and live oak or mesquite savannahs. Comparatively, the Rolling Plains experiences an annual rainfall of 20–28 in. Soils vary from coarse sand to tight clays and shales (Texas Ecoregions—Texas Parks & Wildlife Department 2022). As highlighted by the Yield Gap analysis, there has been a drastic transformation of grasses to juniper-woodland since 1990 (Working Lands for Wildlife 2023). Specifically, in Crockett County, the conversion has amounted to 157 468 ac.

Tom Green County has witnessed a similar shift over a substantial land area, totaling 87 596 ac. Lastly, Schleicher County has undergone a notable transformation, with 86 737 ac. transitioning from grassland to woodland (Working Lands for Wildlife 2023). To combat this issue ranchers at these demonstration ranches have adopted prescribed fire, multispecies grazing, and patch-burn grazing as management strategies. For this study, participants were

granted the opportunity to attend each ranch and see the results of the different management strategies listed above. As a result, ranchers were able to interact with participants, teach them about their specific management practices, and show them the results of those management practices.

Statistical analysis

Data was analyzed using version 29 of the Statistical Package for Social Sciences. To evaluate the statistical significance between participants' pretest and post-test scores following their participation in a workshop, we utilized Welch's *t* test. Additionally, to gauge the magnitude of the observed effect sizes in case of statistical significance, we calculated effect sizes using Cohen's *d* formula. For consistency and to enhance validity of our statistical analysis, we employed standardized scores for all survey questions, including the reversal scoring of for negatively worded Likert-scale questions. When calculating knowledge and attitude change, we used the specific formula below. Finally, respondents who omitted a response to a particular question but answered the remaining questions had their responses excluded from the final mean pretest and post-test calculations for that specific question.

Results

The survey employed in this study consisted of multiple-choice and multiple-answer questions aimed at assessing participants' rangeland literacy and woody plant management strategies. When asked, "Which of the following is/are natural features of rangelands?" the RAP Curriculum + Ground Truthing group exhibited a notable knowledge increase of 12.12%. The pretest mean score for this group was 3.30, with a standard deviation of 1.30, while the post-test mean score was 3.70, with a standard deviation of 0.86. To

account for unequal variances, we conducted a Welch's t test, resulting in $t(199.20) = -2.72, P = 0.007$. The effect size, measured as Cohen's d , was $d = 0.36$, which indicates while there was statistical significance, it was minimal for this question.

The RAP Curriculum and RAP Curriculum+Ground Truthing groups both demonstrated significant knowledge change at 4.03% and 4.52% in determining which “*is/are essential for sustaining rangelands?*”. In the RAP Curriculum treatment, the mean pretest score was 3.72, with a standard deviation of 0.73, while the post-test mean was 3.87, with a standard deviation of 0.5. Welch's t test determined $t(311.78) = -2.19, P = 0.03$. Likewise, the RAP Curriculum+Ground Truthing treatment exhibited a mean pretest score of 3.76, with a standard deviation of 0.76, while the post-test mean was 3.93, with a standard deviation of 0.38. Welch's t test determined $t(171.05) = -2.12, P = 0.04$. The effect size of both groups was $d = 0.24$ and $d = 0.28$, which signifies minute statistical significance.

The RAP Curriculum group displayed the highest knowledge increase of 25.82% regarding species diets of cattle and goats. The pretest mean score was 3.95, with a standard deviation of 0.42, while the post-test mean was 5.00, with a standard deviation of 0.41. Welch's t test deduced $t(321.49) = -2.20, P \leq 0.001$. Additionally, effect size was found to be $d = 2.42$, signifying a large and meaningful difference between pretest and post-test scores.

Significant knowledge improvement in both the RAP Curriculum and RAP Curriculum+Ground Truthing treatments at 10.15% and 8.61% when participants were asked to provide examples of rangelands. In the RAP Curriculum group, the pretest mean score was calculated to be 3.35, with a standard deviation of 0.92, whereas the post-test mean score was 3.69, with a standard deviation of 0.66. Welch's t test established $t(317.36) = -3.84, P \leq 0.001$, with an effect size of $d = 0.42$, indicating a minimal statistical difference between pretest and post-test scores. Similarly, the RAP Curriculum+Ground Truthing treatment illustrated a pretest mean score of 3.37, with a standard deviation of 0.79, while the post-test score was depicted to be 3.66, with a standard deviation of 0.67. Welch's t test displayed $t(218.42) = -3.04, P = 0.003$, with an effect size of $d = 0.41$ respectively, indicating a minimal statistical difference between pretest and post-test scores.

9th–12th grade participants in the RAP Curriculum+Ground Truthing treatment was the only age group that demonstrated the most substantial knowledge change at 13.62% when asked “*Which of the following is/are natural features of rangelands?*”. The pretest score was revealed to be 3.23, with a standard deviation of 1.35, whereas the post-test score was 3.67 with a standard deviation of 0.90. Welch's t test determined $t(180.68) = -2.74, P = 0.007$, with an effect size $d = 0.38$, which indicates a minimal significance between pretest and post-test scores. Interestingly, none of the treatment groups showed statistically significant changes in pretest and post-test scores regarding practices for sustaining rangeland and diet preferences of cattle and goats. However, when asked “*Which of the following are considered rangelands (check all that apply)*,” the 9th–12th age group in the RAP Curriculum treatment recorded substantial knowledge improvement at 21.48%. The Pretest mean score was displayed as 2.98, with a standard deviation of 0.93, while the post-test score was 3.62, with a standard deviation of 0.73. Welch's t test portrayed a $t(113.42) = -4.11, P < 0.001$, with an effect size of $d = 0.75$, indicating a moderate significance between pretest and post-test scores. Of important note, the 9th–12th age groups in the Ranch Tour and RAP Curriculum+Ground Truthing treatments also exhibited significant P values of $P = 0.02$ and $P = 0.002$ and effect sizes of $d = 0.75$ and $d = 0.43$ respectively.

When answering “*I have a clear understanding of what a rangeland is*,” the ranch tour group demonstrated the most significant positive attitude change at 30.49%. The pretest mean score was demonstrated to be 3.64, with a standard deviation of 1.16, while

the post-test mean score was 4.75, with a standard deviation of 1.44. Welch's t test illuminated a $t(34.62) = -4.72, P \leq 0.001$. Remarkably, the effect size was $d = 1.26$, implying a large significant difference between pretest and post-test scores.

It is noteworthy to mention that both the RAP Curriculum, RAP Curriculum+Ground Truthing groups demonstrated significant P values ($P < 0.001$) with medium effect sizes of $d = 0.61$ and $d = 0.79$ for this question. When asked, “*There are benefits to using goats, in addition to cattle, for managing rangelands*,” the RAP Curriculum+Ground-Truthing group revealed significant positive attitude change at 7.32%. The pretest mean score was highlighted to be 4.51, with a standard deviation of 0.63, whereas the post-test score was 4.84, with a standard deviation of 0.43. Welch's t test conveyed $t(202.49) = -4.59, P \leq 0.001$, with an effect size of $d = 0.61$, which implies a moderate statistical difference between pretest and post-test scores.

When asked, “*I have a clear understanding of what a rangeland is*,” the 9th–12th participants in the ranch tour treatment exhibited the most positive attitude change at 36.78%. The pretest mean score was revealed to be 3.48, with a standard deviation of 1.17, while the post-test mean score was 4.76, with a standard deviation of 0.44. Welch's t test illuminated a $t(25.49) = -4.74, P \leq 0.001$. Remarkably, the effect size was determined to be $d = 1.46$, which revealed a large statistical difference between the pretest and post-test scores. Notably, the 9th–12th age groups in the RAP Curriculum and RAP Curriculum+Ground Truthing displayed P values of $P < 0.001$, and effect sizes of $d = 1.08$ and $d = 0.88$ which indicate a large and meaningful statistical difference between pretest and post-test scores.

The 9th–12th participants in the RAP Curriculum+Ground Truthing group demonstrated the most notable knowledge improvement at 7.96% when asked “*There are benefits to using goats, in addition to cattle, for managing rangelands*,” The pretest score was depicted to be 4.52, with a standard deviation of 0.62, whereas the post-test score was 4.88 with a standard deviation of 0.38. Moreover, Welch's t test showed $t(174.392) = -4.91, P \leq 0.001$. The effect size was calculated to be $d = 0.68$, which indicates a modest statistical difference between pretest and post-test scores. Significantly, the college student age group in the RAP Curriculum+Ground Truthing treatment also demonstrated a P value $P < 0.001$, with a medium to large effect size of $d = 0.61$ (Table 2).

Discussion

In this study involving 337 participants, significant improvements in participants rangeland literacy and attitude scores were positively impacted. We failed to reject both of our hypotheses that 1) live demonstration and personal experience were attributed as effective methods for improving rangeland literacy and attitudes among participants and 2) K-12 participants experienced the most significant knowledge and attitude transformation. Furthermore, these findings highlight three significant points for discussion: 1) *Web-based learning is effective*, 2) *Blended learning yields positive results*, and 3) *High school students benefitted the most from learning*.

These results provide a foundation for educators and outreach professionals to develop more impactful public education materials aimed at “creating agents of change.” The significant improvements in knowledge and attitude underscore the need for interactive and experiential learning approaches. Educators can leverage these findings to prioritize strategies such as hands-on demonstrations and blended learning models to effectively engage diverse audiences. Importantly, the results demonstrate that K-12 participants, particularly high school students, experienced the most profound transformation. This highlights the critical role of early and targeted educational interventions in shaping future generations who are informed and motivated to act as agents of change. Ad-

Table 2

Overall attitude change for by age group for RAP Curriculum, RAP Curriculum + Ranch Tour, Ranch Tour, and RAP Curriculum + Ground Truthing treatment groups.

Q6: There are benefits to using goats, in addition to cattle, for managing rangelands.								
RAP Curriculum treatment group								
Age group	PRE (raw)	SD	POST (raw)	SD	% Improved	<i>t</i>	<i>P</i>	<i>d</i>
9th–12th ¹	4.54	0.67	4.70	0.63	3.52%	–1.36	0.18	0.25
College students ²	4.56	0.80	4.93	0.26	8.11%	–3.59	<0.001	0.61
Adult ³	4.43	0.80	4.53	0.82	2.26%	–0.57	0.57	0.13
RAP Curriculum + Ground Truthing treatment group								
Age group	PRE (raw)	SD	POST (raw)	SD	% Improved	<i>t</i>	<i>P</i>	<i>d</i>
9th–12th ⁴	4.52	0.62	4.88	0.38	7.96%	–4.91	<0.001	0.68
College students ⁵	4.40	0.70	4.50	0.71	2.27%	–0.32	0.75	0.14

¹ Pretest = 62; post-test = 55.² Pretest = 68; post-test = 67.³ Pretest = 47; post-test = 30.⁴ Pretest = 104; post-test = 97.⁵ Pretest = 11; post-test = 10.

ditionally, the findings advocate for the integration of web-based learning, which has proven to be an effective complement to traditional methods. As technology becomes increasingly central to education, educators should adapt their outreach approaches to incorporate digital tools alongside in-person learning. By doing so, they can reach broader audiences and reinforce learning outcomes.

Overall, the study emphasizes the value of tailoring educational strategies to different audiences and age groups to maximize impact. For educators, the data signals a shift toward more interactive, blended, and age-appropriate approaches to education and outreach to cultivate lasting change and inspire stewardship in rangeland management.

Web-based learning is effective

Identifying knowledge and attitude change associated with each treatment group is crucial to providing a comprehensive understanding of the most effective methods for improving rangeland literacy among participants. Our results revealed that the RAP Curriculum treatment group experienced one of the most statistically significant increases in knowledge and attitude change for survey Q3, “(→) eat more grasses and (→) eat more leaves and twigs of shrubs and small trees,” and Q4, “Which of the following are considered rangelands (check all that apply).” Research on web-based learning has shown that web-based learning is an effective means of educating learners. A comparative study by Shenk (2008) involving pesticide applicators explored the efficacy of interactive computer-based training against conventional instructional approaches. Findings revealed that interactive computer training delivered an equivalent level of effectiveness to traditional methods of instruction, all while demanding only half the time investment. These findings were corroborated by a separate study conducted by Fishel and Ferrell (2010) which found that pesticide applicators strongly agreed online learning was equally as effective as conventional instructional methods. Web-based learning aligns well with constructivist learning theory, which emphasizes the active construction of knowledge through interaction, reflection, and engagement with meaningful content. According to this theory, learners build new understandings by integrating prior knowledge with new experiences, which can be effectively facilitated through digital platforms.

Additionally, web-based learning facilitates collaborative learning, a core tenet of constructivism, by enabling communication and interaction among learners across diverse geographical and cultural contexts. Discussion boards, live webinars, and group projects create opportunities for peer learning, fostering the social dimension of knowledge construction emphasized by constructivist the-

orists such as Vygotsky. The accessibility and flexibility of web-based platforms further enhance their effectiveness. Learners can revisit content as needed, explore additional resources, and engage with materials in a self-directed manner, all of which empower them to take ownership of their learning process. This autonomy is critical in helping learners internalize and transfer knowledge to real-world contexts. In the context of education and outreach, web-based learning serves as a powerful tool to disseminate information widely while allowing individuals to actively engage with and apply the knowledge in a manner consistent with constructivist principles. By providing authentic, interactive, and collaborative learning experiences, web-based approaches enable learners to transfer knowledge effectively into practice.

Based on the results of the RAP Curriculum treatment, it becomes evident that web-based learning can prove to be an effective means of educating diverse age groups. We suggest that educators be open to including interactive web-based curriculum in their classrooms. However, while web-based learning was shown to be effective, we acknowledge that one-size teaching lessons do not fit all.

Blended learning yields positive results

Additionally, the RAP Curriculum + Ground Truthing treatment achieved significant knowledge and attitude improvement for survey Q1, “Which of the following is/are natural features of rangelands?”, Q2, “Which of the following is/are essential for sustaining rangelands?”, and Q6, “There are benefits to using goats, in addition to cattle, for managing rangelands.” Research on blended learning that combines web-based training and experiential learning has shown these methods to be an effective means of improving student learning outcomes. For example, a study by Li et al. (2020) which combined online instruction with a field trip, found this approach significantly improved students’ abilities to identify herbal plants. Additionally, a meta-analysis conducted by Liu et al. (2016) indicated that blended learning methods were either equal to or more effective than nonblended approaches in improving students’ knowledge and learning outcomes. By using a blended learning approach, educators can maximize the advantages of using both web-based training and field-excursions. Nonetheless, we acknowledge that time constraints can pose challenges for both educators and students when attempting to incorporate both teaching methods.

High school students benefitted the most from learning

Furthermore, this study sought to determine if one age group was more influenced by a treatment than others. Our findings

revealed that the 9th–12th age group in the RAP Curriculum, RAP Curriculum+Ground Truthing, and Ranch Tour treatments presented the most statistically significant results for survey Q1, “Which of the following is/are natural features of rangelands?”, Q4, “Which of the following are considered rangelands (check all that apply),” Q5, “I have a clear understanding of what a rangeland is,” and Q6, “There are benefits to using goats, in addition to cattle, for managing rangelands.” This significant change in knowledge is unsurprising as youth come with less knowledge and fewer life experiences than their adult counterparts (Bransford et al. 1999). Furthermore, it’s worth mentioning that college students within the RAP Curriculum treatment demonstrated notable improvements in their attitudes, specifically regarding Likert-scale questions 5 and 6, which gauged their perceived understanding of rangelands and the advantages of multispecies grazing.

Implications

These findings have implications in three areas: 1) Enhancing the effectiveness of outreach and extension programs for teaching rangeland literacy, 2) providing educators and prescribed fire advocates with resources they can use to teach rangeland literacy, and 3) creating agents of change. The first implication is that educators and extension professionals can use the study’s findings to improve their outreach and extension programs related to rangeland literacy. The second implication of this study is that readily available web-based and hands-on curriculum can be accessed by educators and prescribed fire advocates to educate learners about the management strategies of prescribed fire, multispecies grazing, and patch-burn grazing. Creating agents of change equipped with the knowledge of best management practices is crucial to the preservation of vulnerable grassland savannas facing WPE. The insights gained by youth, future landowners, and range managers from this study may lead to the adoption and promotion of best management practices. On a larger scale, the knowledge gained by participants may not only contribute to the safeguarding of vulnerable grassland ecosystems, but also lay the foundation for the next-generation professionals, future leaders, and informed voters equipped with the knowledge of best management practices to preserve and protect grasslands from WPE.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

CRedit authorship contribution statement

Erika Sullivan: Writing – original draft, Methodology, Investigation, Formal analysis. **Sakina Dixon:** Writing – original draft, Formal analysis, Data curation. **Morgan L. Treadwell:** Writing – review & editing, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization.

References

- Bransford, J.D., Brown, A.L., Cocking, R.R., 1999. How people learn: brain, mind, experience, and school (pp. xiv–xv), 436. National Academy Press, Washington, DC, p. 276.
- Dimitrov, D.M., Rumrill Jr, P.D., 2003. Pretest-posttest designs and measurement of change. *Work* 20 (2), 159–165.
- Fishel, F., Ferrell, J., 2010. Does user age differ in perceptions of online learning for certified and licensed pesticide applicators. *Journal of Extension* 48 (5).
- Harr, R.N., Wright Morton, L., Rusk, S.R., Engle, D.M., Miller, J.R., Debinski, D., 2014. Landowners’ perceptions of risk in grassland management: woody plant encroachment and prescribed fire. *Ecology and Society* 19 (2), 41. doi:10.5751/es-06404-190241.
- Hoffmann, W.A., 1999. Fire and population dynamics of woody plants in a neotropical savanna: matrix model projections. *Ecology* 80 (4), 1354–1369. doi:10.1890/0012-9658(1999)080[1354:fapdow]2.0.co;2.
- Kreuter, U.P., Wilkins, H.E., Clendenin, M.M., 2008. The influence of demographic and environmental factors on perceptions of prescribed rangeland burning. *Rangeland Ecology & Management* 61 (3), 252–259. doi:10.2111/07-047.1.
- Liao, J.D., Boutton, T.W., Jastrow, J.D., 2006. Organic matter turnover in soil physical fractions following woody plant invasion of grassland: evidence from natural 13C and 15N. *Soil Biology and Biochemistry* 38 (11), 3197–3210. doi:10.1016/j.soilbio.2006.04.004.
- Li, L., Tam, C.W., Wang, N., Cheung, F., Zhou, Q., Zhang, C., Cheng, C.S., Xiong, L., Feng, Y., 2020. Effectiveness of blending E-learning with field trip on Chinese herbal medicine education: quasi-experimental study. *BMC Complementary Medicine and Therapies* 20 (1), 248. doi:10.1186/s12906-020-03034-y.
- Liu, Q., Peng, W., Zhang, F., Hu, R., Li, Y., Yan, W., 2016. The effectiveness of blended learning in health professions: systematic review and meta-analysis. *Journal of Medical Internet Research* 18 (1), e2. doi:10.2196/jmir.4807.
- Matzke, C., Sullivan, E., Treadwell, M. Texas A&M AgriLife Extension, 2023. Rangeland analysis platform. Texas A&M AgriLife Extension Service, College Station, TX, USA Available at: <https://cdn-de.agrilife.org/extension/departments/rwfm/rwfm-pu-407/publications/files/rangeland-analysis-platform.pdf> Accessed 10 January 2025.
- Shenk, M., 2008. Improving PAT and IPM training through an interactive training/testing program. *Journal of Pesticide Safety Education* 1, 11–14.
- Su, H., Liu, W., Xu, H., Wang, Z., Zhang, H., Hu, H., Li, Y., 2015. Long-term livestock exclusion facilitates native woody plant encroachment in a sandy semiarid rangeland. *Ecology and Evolution* 5 (12), 2445–2456. doi:10.1002/ece3.1531.
- Sullivan, E., Matzke, C., Treadwell, M., 2023. Using the rangeland analysis platform to measure landcover change. *The Prairie Project* 1–11. https://uploads-ssl.webflow.com/60143e4f3362793ccc653755/64da32fe614b0b7b23111587_using-the-rangeland-analysis-platform-to-measure-landcover-change.pdf.
- Symstad, A.J., Leis, S.A., 2017. Woody encroachment in northern Great Plains grasslands: perceptions, actions, and needs. *Natural Areas Journal* 37 (1), 118–127. doi:10.3375/043.037.0114.
- Taylor, C.A., 2008. Ecological consequences of using prescribed fire and herbivory to manage Juniperus encroachment. *Western North American Juniperus Communities* 196, 239–252. doi:10.1007/978-0-387-34003-6_13.
- Texas Parks & Wildlife Department., 2011. (2011, January 26). Texas ecoregions. <https://tpwd.texas.gov/education/hunter-education/online-course/wildlife-conservation/texas-ecoregions>.
- The Prairie Project. (2020). The Prairie Project. www.theprairieproject.org.
- USDA Natural Resources Conservation Service., 2023. Working Lands for Wildlife. <https://www.nrcs.usda.gov/programs/initiatives/working-lands-for-wildlife>.
- Toombs, T.P., Fuhlendorf, K.E., Dougherty, S.T., Engle, D.M., 2017. Managing fire for conservation and livestock production goals in mesic grasslands. *Rangeland Ecology & Management* 70 (3), 337–345. doi:10.1016/j.rama.2016.12.001.
- Twidwell, D., Rogers, W.E., Fuhlendorf, S.D., Wonkka, C.L., Engle, D.M., Weir, J.R., Kreuter, U.P., Taylor, C.A., 2013. The rising Great Plains fire campaign: citizens’ response to Woody Plant encroachment. *Frontiers in Ecology and the Environment* 11 (s1), e64–e71. doi:10.1890/130015.
- Twidwell, D., Wonkka, C.L., Sindelar, M.T., Weir, J.R., 2015. First approximations of prescribed fire risks relative to other management techniques used on private lands. *PLoS One* 10 (10), e0140410.
- Van Auken, O.W., 2000. Shrub invasions of North American semiarid grasslands. *Annual Review of Ecology and Systematics* 31, 197–215. <http://www.jstor.org/stable/221730>.
- Wilcox, B.P., Birt, A., Archer, S.R., Fuhlendorf, S.D., Kreuter, U.P., Sorice, M.G., van Leeuwen, W.J., Zou, C.B., 2018. Viewing woody-plant encroachment through a social-ecological lens. *BioScience* 68 (9), 691–705. doi:10.1093/biosci/biy051.