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Conduction of Biological Research and the Partial Implementation of Learned Scientific Practices into a Middle School Science Classroom

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By
Aaron Kidd
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Conduction of Biological Research and the Partial Implementation of Learned Scientific Practices into a Middle School Science Classroom

A THESIS

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By Elizabeth A. Allan
____

Committee Chairperson

Victoria Jackson
Victoria Jackson (May 5, 2020)
____

Committee Member

Mike Nelson
Mike Nelson (May 5, 2020)
____

Committee Member

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ABSTRACT OF THESIS

University of Central Oklahoma

Edmond Oklahoma

NAME:

Aaron Emmanuel Kidd

TITLE OF THESIS:

Conduction of Biological Research and the Partial Implementation of Learned Scientific Practices into a Middle School Science Classroom

DIRECTOR OF THESIS:

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ABSTRACT:

Due to the dual nature of this thesis project, the abstract, like the rest of the written work, will be presented in two parts. The first section will outline the biological work that was conducted within Pontotoc Ridge Preserve in southcentral Oklahoma. The second section will describe the in-class research that was designed and conducted in a local Oklahoma 7th grade science classroom following the conclusion of the biological research project. This overarching thesis design was selected so that practical yet realistic scientific research was conducted prior to the implementation of similar scientific practices into a classroom

setting. In this way, as a classroom instructor, I was capable of utilizing personal research experience to generate a more representative classroom science experience.

Chapter 1: Effect of Baiting Regime and Canopy Cover upon Occupancy and Detection of Mesocarnivores: Pontotoc Ridge Preserve.

Apex predator populations are experiencing rapid decline with continued global habitat fragmentation. Mesocarnivores (mid-level predators) are expected to partially assume the ecological niche of once prevalent top predators. Thus, acquiring data regarding the factors that influence whether or not a mid-level carnivore species will exist in a particular location is of significant interest.

Difficulty in accurately surveying mesocarnivores derives from imperfect detection methods in which inadequate data can result in false assumptions concerning the presence or absence of a species. Occupancy models address the problem of non-detection error by analyzing detection and occupancy through long-term observation. Occupancy is affected by site-specific variables such as vegetation, whereas detection can be influenced by non-constant variables such as temperature or time of day.

Twenty-five remotely activated camera traps were placed in Pontotoc Ridge Preserve, Pontotoc Oklahoma from May 2018 – September 2018 in order to determine the impact that canopy cover has upon occupancy and to determine the effectiveness of specific baiting regimes upon detection. Cameras were baited on a randomly assigned rotation and were checked on a biweekly basis.

Image captures of individuals were highest for coyote and raccoon, constituting approximately 98% of all images, whereas images of bobcat, opossum, and striped skunk were too few for analyses. Most highly supported models suggested that canopy cover held little influence upon site occupancy for coyote and that baiting regime had little impact upon detection. For raccoon, the models were less clear. Models in which a high level of canopy cover and canned tuna was used as the baiting regime were supported. However, models in which neither of these variables held influence maintained sufficient support.

These results may suggest some important implications regarding future surveys of mesocarnivores in southcentral Oklahoma. Primarily, future surveys may need to consider the impact that canopy density may have upon a unique species' site selection. Secondarily, this work may suggest that for species-specific survey efforts, bait selection may play an important role in attracting individuals of a particular species. It is important to note, however, that greater research is necessary to confirm the suggestions offered by this work, as the survey period was limited to only a single season.

Chapter 2: Assessing the Effect of Argumentation upon Student Content Knowledge and Perception of Science in a Middle School Science Classroom.

Since the release of the 2012 Framework for K-12 Science Education, educational institutions have been tasked to increase scientific literacy through the implementation of more robust science standards. The Framework identifies three key dimensions of science education: Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. The Scientific and Engineering Practices are composed of a variety of broad

science-oriented skills such as engineering, mathematics, and argumentation. However, the effectiveness of argumentation has not yet been fully explored, particularly in middle school classrooms.

In the spring semester of 2019, 151 7th grade students participated in two treatment and three control science curricular units. In treatment units, students were presented with a unit-specific phenomenon and provided a limited time frame to develop naïve explanatory models (those lacking scientific data). Classes then engaged in student-led argument sessions to debate and further develop their proposed initial models. Pre- and post-assessment data were collected alongside a survey intended to gauge student interest in science, as well as determine the level of importance students placed upon scientific study.

Pre- and post-assessment results indicated significantly higher content knowledge growth in Honors courses following treatment units while mid-low performing classes showed little difference regardless of unit type. Despite generally positive student responses collected through randomly selected interviews following argumentation-driven lessons, treatment sessions had no significant impact upon student perceptions of science as a subject area of study.

These results may have important ramifications regarding the effectiveness of utilizing argumentation instructional techniques within the middle school classroom setting. Primarily, it may be important to consider the skill and content knowledge level of the students prior to engaging in argumentation-styled lessons. Less proficient students may require more significant guidance and supportive tools in order to more effectively engage in the development and analysis of naïve models. Future research should analyze the

effectiveness of such strategies over a longer period of time and with similarly distributed student levels. Further, future research should analyze students of a greater range of socio-economic backgrounds, requiring analysis of students from a variety of school districts.

INTRODUCTION

Modern technology has all but ensured that even the least connected individuals are inundated daily with the near endless capability of scientific tools and knowledge. As science has become an increasingly integral part of modern life, science educators, stakeholders, politicians, and corporations throughout the United States have sought to improve upon the scientific literacy of the American populace. This shared goal led to the current recognition that previous educational standards in science were simply not sufficient to develop a truly versatile and knowledgeable population in the field of science (The National Academies Press, 2012). A groundbreaking document, The Framework for K-12 Science Education, was developed in response to an increasing cry for improved science education outcomes and within this document, researchers, teachers, professors, etc. outlined their image of a truly comprehensive science education (The National Academies Press, 2012).

The Framework for K-12 Science Education centered around multiple assumptions regarding science education:

1. Children naturally engage in scientific exploration.
2. Greater scientific understanding requires a focus upon core concepts.
3. Scientific knowledge develops over a period of time.
4. Science is not simply a body of knowledge, but is also a practice.
5. Classroom science should engage students at a personal level.
6. Equity in science education requires universally rigorous standards.

If the assumptions that guide The Next Generation Science Standards are indeed true, the implications for a student of science are clear. It is imperative that students are provided a broad but meaningful understanding of scientific processes buoyed by a supportive base of scientific content. Grasping science, according to The Framework, requires actual participation in the process supported with instruction that offers a body of scientific knowledge to guide that participation. Accepting that true scientific knowledge is gained through experience, it is imperative that students at all levels directly engage in the process of scientific exploration. For these reasons, this project, and ultimately this document, is separated into two distinct chapters. The first chapter outlines the direct scientific experience I gained through the development, conduction, and analysis of a biological research project. The second chapter describes the implementation of my learned practices into a middle school science classroom and the ultimate results of that integration.

Chapter 1: Effect of Baiting Regime and Canopy Cover upon Occupancy and Detection of Mesocarnivores: Pontotoc Ridge Preserve

Aaron E. Kidd

University of Central Oklahoma

INTRODUCTION

Mesocarnivores

Mesocarnivores, which are carnivores of typically < 15 kg (Roemer et al. 2009) comprise the majority of carnivore species, though they have historically received less research attention than their larger apex counterparts. A lack of research and public interest in mesocarnivores is thought to be the result of historical awe produced by the sheer size and threat of larger carnivores in conjunction with the abundance of many mesocarnivore species (Roemer et al. 2009; Sergio et al. 2008). Despite the apparent indifference towards these species, it is well established that mesocarnivores operate significant ecological roles within their respective ecosystems, particularly in areas where once prevalent apex predator populations have seen significant decline (Gompper 2002; Nishijima et al. 2014; Taylor et al. 2016).

Mesocarnivore species are varied in their ecological niches, fulfilling roles at various levels as predators, prey, specialists, generalists, and scavengers (Roemer et al. 2009). Thus, mesocarnivore influence extends far beyond simple prey population control models. Significant alterations to their population may have unforeseen impacts upon the stability of biological interactions within an ecosystem (Khalil et al. 2014; Nishijima et al. 2014). Globally, many mesocarnivore species are experiencing population booms thought to be the result of decreased predation from larger carnivores, increased successful anthropogenic interactions, and unintended introductions into new territories (Gompper 2002; Khalil et al. 2014; Sergio et al. 2008) As mesocarnivores are raised to the peak of ecological food chains, greater understanding regarding their territorial requirements alongside a toolbox of effective detection strategies is necessary to ensure that future management efforts are cost-efficient and effective.

Occupancy Modeling

Modern species distribution modeling has progressed beyond measures that indicate only the presence or absence of studied species. Simple detection/non-detection surveys provide little applicable data regarding species of interest and are therefore of little use in land management and conservation (Long et al. 2008). Additionally, traditional survey models are often flawed in their design as many organisms have significant territorial ranges, and an overlap of ranges can result in inaccurate assumptions regarding population size and density (MacKenzie et al. 2002). Similarly, the probability of detection of most species is significantly < 1 (MacKenzie et al. 2002). For this reason, it is not uncommon for individual organisms and or representatives of an entire species to remain entirely undetected during a survey (MacKenzie et al. 2002). Despite known difficulties in detecting particular species, traditional survey techniques required an assumption of perfect detection, introducing severe inaccuracies in predicting the absence of a species and negatively skewing results (MacKenzie et al. 2002; MacKenzie and Royle 2005; Olea and Mateo-Tomás 2011).

In order to address the inherent weaknesses of traditional detection/non-detection surveys, Pollock (1982) recommends a commonly used, repeated sampling site-constant design. This is because occupancy, the "probability of a site being occupied by a species" is fundamentally tied to an unequal detection (Guillera-Arroita et al. 2011). Detection, unlike occupancy, is merely the probability that a species can be observed and identified (MacKenzie et al. 2002; Pollock 1982). Estimating occupancy therefore requires a careful consideration of factors that may impact detection such as time of day, temperature, season, and attractant employed (Ferreras et al. 2018). Following this logic, sampling efforts that target particular species increase the probability of detection, and thereby decrease the likelihood of inaccurate reporting (Ferreas et al. 2018).

Occupancy modeling (MacKenzie et al. 2002) is an effective technique designed for particularly elusive species for whom detection probabilities are low. The sampling technique allows for a robust estimation of occupancy despite imperfect detection frequencies while simultaneously considering variables that may impact detection. Occupancy estimates also take into consideration site-specific variables such as canopy cover, distance from water, and soil composition. Applying this sampling technique, predictions can then be made regarding the probability of a species occupying other unique sites based upon the site's inherent characteristics (MacKenzie et al. 2005; Olea and Mateo-Tomás 2011).

Remote Camera Trapping

Occupancy estimates for mesocarnivores can prove to be particularly difficult to determine because of their typically evasive and nocturnal nature in conjunction with their rather larger territorial ranges. Cryptic coloration that is common throughout mesocarnivore species only compounds the difficulty of detection (Hoffman 1996; O'Connell et al. 2006). More traditional techniques for studying carnivores typically require a direct capture and examination technique. These methods are greatly invasive, disruptive, and impractical both in cost and effectiveness (Gompper et al. 2006). A less invasive and more practical method for mesocarnivore survey involves the use of remotely-activated camera traps. As it does not require direct human contact with organisms, it can significantly reduce disruptive human-animal interaction as well as the necessary field hours. Despite the economic benefits of utilizing camera traps, the success of such studies varies widely depending upon baiting practices, camera placement, and the particular species of interest (Kelly and Holub 2008). These problems, combined with the possibility of human or animal trap disturbance and ineffective attraction of desired species, can reduce the overall effectiveness of such studies. However, in general, camera trapping can provide an effective means through which to survey mesocarnivores with different trap and bait designs available depending upon specific needs (Kelly and Holub 2008).

Research Goals

For this project, several distinct goals were identified prior to data collection.

1. Identify all mesocarnivore species found within Pontotoc Ridge Preserve.
2. Identify regions of occupancy for each species within the preserve, examining the impact of canopy cover upon species occupancy.
3. Determine the effect of baiting regime upon species detection.

Survey Location:

The study site is protected and managed by The Nature Conservancy and is located in southcentral Oklahoma. Located approximately 32 kilometers from Ada, Oklahoma, Pontotoc Ridge Preserve spans the borders of Pontotoc and Johnson counties (34.524352, -96.605879). Consisting of approximately 1200 hectares, the preserve (Fig. 1) presents a variety of ecosystem variation including bottomland forest, mixed-grass and tall-grass prairies, and interspersed limestone outcroppings. Off-limits to public use, Pontotoc Ridge

Preserve staff are actively pursuing the maintenance of the preserve's native species. Simultaneously, a similar goal of the preserve is to prevent the further spread of invasive species within the preserve through the use prescribed disturbance regimes (The Nature Conservancy 2017).

a. b.

Fig. 1- Photographs of Pontotoc Ridge Preserve taken at camera sites 13 (a) and 9 (b) by Reconyx HC600 infrared motion-activated cameras during the summer of 2018.

Focal Mesocarnivore Species

Bobcat (*Lynx rufus*)

Bobcat territory extends across the majority of the United States and Canada, and have been detected across much of Oklahoma (Lariviére and Walton 1997). Further, bobcat are thought to be ecologically resourceful, with generalist capabilities that allow them to exist in a wide range of habitat (Lariviére and Walton 1997). As a similarly sized carnivore, bobcat maintain some dietary overlap with coyotes (Thornton et al. 2004). However, Thornton et al. (2004) also found that the overlap was not a significant barrier to cohabitation largely due to differences in prey selection based upon size with bobcat more commonly selecting smaller rodents. Though coyote are thought to inhabit Pontotoc Ridge, their presence is unlikely to directly negatively impact bobcat detection within the preserve.

Coyote: (*Canis latrans*)

Unlike many mesocarnivore species, coyotes have seen some population increases that coincide with their spread across the United States (Hidalgo-Mihart et al. 2004). It is suspected that the apparent increase in distribution and population are due largely to the species' ability to successfully capitalize upon human-induced clearings of previously forested regions and coexist in moderately altered environments (Hidalgo-Mihart et al. 2004). Although coyotes are capable of inhabiting heavily developed territories, human-avoidance remains a strong driver during territory selection (Gehrt et al. 2009). Visitor access to Pontotoc Ridge is highly restricted and it is quite likely that coyote populations are well established within the preserve.

White-tailed deer populations within the preserve have grown largely uncontrolled due to culling limitations placed upon management staff. Although coyotes are thought to be relatively ineffective predators of adults, neonate predation is well-documented (Kilgo et al. 2014; Stout 1982). Thornton et al. (2004) found that ungulates comprised over 36% of all remains within scat samples. In addition to the seclusion that Pontotoc Ridge Preserve offers, the local white-tailed deer population almost certainly assists in the support of a robust coyote population.

Raccoon: (*Procyon lotor*)

With a geographic range that spans the majority of North and South America, raccoon are a highly adaptive species whose ability to coexist with human development has contributed greatly to their success (Kamler et al. 2003). It is only areas of very limited rainfall where populations have truly struggled to become established (Kamler et al. 2003). However, continued human development within these ranges has led to successful colonization of previously unoccupied territories (Kamler et al. 2003). Raccoon regularly inhabit hardwood forests where water is abundant and are also well documented in edge habitat (Rulison et al. 2012). Pontotoc Ridge Preserve is dominated by hardwood Cross Timbers interrupted by small springs and streams (The Nature Conservancy 2017) likely providing ample habitat for raccoons.

Striped Skunk (*Mephitis mephitis*)

Much research has been completed on the distribution of the striped skunk and their presence in Oklahoma is well documented (Halloran and Glass 1959; Lewis 1972; Schnell and Grzybowski 1985). Their generalist tendencies and the continued decrease in apex predators have resulted in an expansion of striped skunk into many previously unestablished areas including relatively urban ecosystems (Baldwin et al. 2004; Broadfoot, et al. 2001). Baldwin et al. (2004), described some site selection preferences for striped skunk that included small patches of forest with significant edge habitat broken by rather large open areas. Pontotoc Ridge Preserve is composed of a matrix landscape dotted with interspersed "oakforests, savannas, mixed-grass and tallgrass prairies, springs and cool running streams" likely providing sufficient habitat for striped skunk (Nature Conservancy 2017).

Virginia Opossum (*Didelphis virginiana*)

As the single native marsupial that currently exists in the United States, the Virginia opossum has expanded its range through intentional and accidental introduction to a large area of the United States (Gwinn et al. 2011) It was once predicted that opossums would quickly reach the limits of their northern expansion due to their dependence on warm, tropical climates; however, recent data has indicated a much larger potential range with individuals observed as far north as Ontario, Canada (Kanda and Kelt 2005). Opossum have many of the same habitat requirements as raccoon and have been regularly detected in the Cross Timbers ecoregion of Oklahoma (Kasparian et al. 2004). The dominant habitat makeup found within the boundaries of Pontotoc Ridge Preserve likely sustains a strong opossum presence.

MATERIALS AND METHODS

Camera Placement

During the 2018 summer season, (May 31 – September 8) 25 Reconyx HC600 infrared motion-activated cameras were placed within the boundaries of Pontotoc Ridge Preserve (Fig. 2).

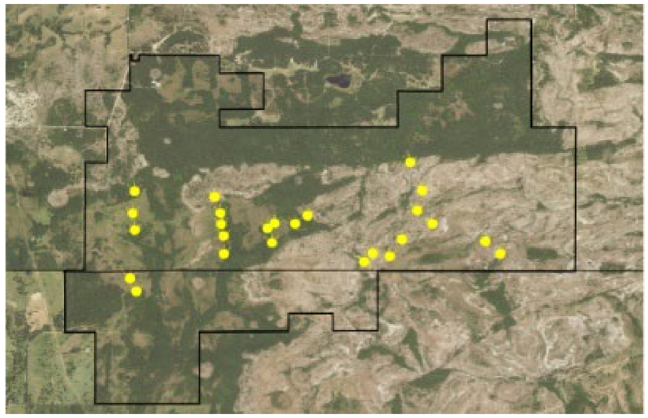

Fig. 2- Survey camera locations for 25 Reconyx HC600 infrared motion-activated cameras placed during the summer of 2018.

Approximate survey sites were selected prior to visiting the preserve, and were chosen to represent the variety of habitat types found within the preserve. Cameras were attached to trees at a height of approximately one meter and aimed at a slight angle towards the ground. In order to increase visibility during detections, most camera sites were located in small clearings or cameras were intentionally aimed away from dense foliage. Cameras were assigned a label prior to placement and GPS coordinates (Garmin GPSMAP 64S, Olathe, KS) were recorded as cameras were placed during the initial visit.

Baiting Regimes

Each survey site was randomly assigned a rotating baiting regime (canned cat food, canned tuna, commercial lure, raw chicken, unbaited) prior to the first sampling period. Baits were selected based upon recommendations put forth in Schlexer (2008) with baits chosen for their propensity to attract particular mesocarnivore species. Each survey location employed a brick and chicken wire bait trap (Fig. 3) to decrease bait theft and increase potential attraction. Bait traps were placed approximately two meters from the camera attachment point and baits were securely placed within each trap at the beginning of each survey period.

Fig. 3- Brick and chicken wire bait traps used at each camera location during the summer of 2018 in Pontotoc Ridge Preserve.

Survey Occasions

Each survey site was visited twice a month for service. Cameras were resupplied with fresh batteries and memory cards. Filled cards were collected for analysis and bait traps were replenished with fresh bait following individual site baiting regimes. Adjustments to camera angle were made as necessary based upon image quality. Bait trap retrieval was occasionally required as raccoon were repeatedly observed attempting to remove bait traps from survey sites. Disturbances to survey sites were recorded and any additional vegetative growth with the potential to distort image quality or prematurely activate cameras was removed.

In order to limit unnecessary images of moving vegetation, cameras were set to a medium level of sensitivity with a one-minute rest period between each burst of five image captures. Captured images were examined for mesocarnivore species which were then identified through visual markers. Detection histories for each site were established under the assumption of site independence in which detection at one site does not impact detection at another site (MacKenzie et al. 2002). Detection periods constituted three days of sampling. Within a data matrix, sites were assigned a value of either a 1 or a 0 for each sampling period with a 1 indicating detection, and a 0 indicating no detection of a particular species. Canopy cover was selected as the site-specific occupancy covariate as in small carnivores this factor has been shown to influence habitat selection (Santos et al. 2011). Bait regime was selected as the primary detection covariate as prior work has indicated that bait type is thought to significantly impact detection efforts (Schlexer 2008). Time and date of capture, camera number, number of images, bait employed at time of detection, number of identifiable individuals, temperature, and moon phase were also recorded following each detection. Images in which the captured organism was not easily identified (covered by vegetation, poor image quality, lighting, etc.) were discarded.

Canopy Measurements

Canopy cover, a factor that directly impacts light penetration within forested ecosystems, is the percentage of each sampled site obscured by vegetation (Vora 1988). Due to its presumed impact upon mesocarnivore site selection, canopy cover was selected prior to data collection as a site occupancy covariate. Site cover was estimated for each survey location utilizing a traditional convex reflective densiometer (Forestry Suppliers

Spherical Crown Densiometer, Jackson, MS). Densiometer measurements utilize a convex mirror with an engrained grid pattern. Canopy cover is then estimated by counting each portion of the grid obscured by the reflected canopy (Vora 1988). At each survey site, measures were taken in each of the four cardinal directions approximately 3 meters from the camera attachment point. Measurements were then averaged to estimate total average canopy cover for each survey site.

Results

During the 100-day collection period, total detection rates varied widely by species but were generally low (Hoffman 1996; O'Connell et al. 2006). Sampling occasions were organized into three-day periods resulting in 34 equal sampling occasions (T=34). However, the final sampling period had to be shortened due to unexpected early camera retrieval and therefore only included two days of data collection. Coyote was the most commonly detected species constituting 50 of the 90 total detections with naïve occupancy estimates for coyote totaling ($n._{coyote}$ = 0.40). Raccoon were frequently observed, accounting for 35 of the 90 total detections, resulting in a naïve occupancy estimate of 0.64 ($n._{raccoon}$ = 0.64) (Fig. 4). Opossum were observed rarely, achieving only 4 unique detections and resulting in a subsequently low naïve estimate of occupancy ($n._{opossum}$ = 0.08) (Fig. 4). Bobcat, like opossum, were detected rarely with the detection of only a single bobcat (Fig. 4). A result of low detection values, naïve estimates of occupancy for bobcat was similarly low ($n._{bobcat}$ = 0.04) (Fig. 4). Skunk were not detected at any site during the survey and thus analysis was not possible.

a) b)

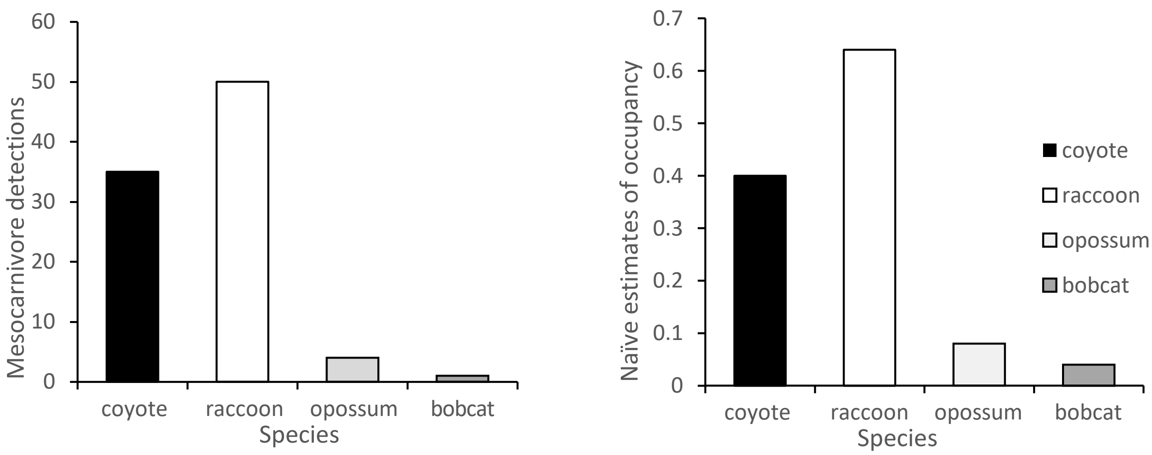

Fig. 4.- Mesocarnivore detections categorized by species (a) and naïve estimates of occupancy (b), Pontotoc Ridge Preserve, Oklahoma, May 2018 - September 2018.

Camera survey locations differed widely in canopy cover. Cover estimates ranged from 0.00 to 0.97, and mean canopy cover for all sites was 0.33 ± SD 0.37. Mean canopy cover for detection sites differed between species (coyote=0.28 ± 0.38, raccoon= 0.45 ± 0.34, opossum=0.89 ± 0.04, bobcat=.01) (Table 1).

Species	Mean	Range
coyote	0.28 ± SD 0.38	0-0.95
raccoon	0.43 ± SD 0.34	0-0.97
opossum	0.89 ± SD 0.04	0.87-0.92
bobcat	.01	0.00

Table 1.- Canopy cover estimates at camera survey sites where individual species were detected in Pontotoc Ridge Preserve, Oklahoma, May 2018 – September 2018. Estimates were collected utilizing a convex reflective densiometer.

Occupancy and detection models were generated via PRESENCE (12.25) software (Hines 2006) and top weighted models were selected using Akaike Information Criterion. Occupancy models receiving support differed between mesocarnivore species (Table 2). Best-fit models for coyote indicated that occupancy was not impacted by site canopy cover and bait regime had little impact upon detection (Table 2). Raccoon occupancy models in which canopy cover acted as a site-specific covariate and in which detection was impacted by baiting regime received the greatest support (Table 2). However, maintaining a ΔAIC value of less than 2, modeling in which baiting regime held little impact upon detection could not be dismissed (Table 2). Models for bobcat, opossum, and skunk were not examined as detection frequencies were insufficient for analysis. Analysis of the role of baiting regime in species detection identified a negligible impact of bait upon coyote detection (Figure 5). In contrast, canned tuna received significant support as the most effective attractant for raccoon (Figure 5).

Coyote (*Canis latran*)

Model	AIC	ΔAIC	K	AIC Weight
$\psi\psi$(.),p(.)	187.09	0.00	2	0.9219

Raccoon (*Procyon lotor*)

Model	AIC	ΔAIC	K	AIC Weight
$\psi\psi$(CanopyCover),p(BaitType)	268.30	0.00	7	0.6332
$\psi\psi$(CanopyCover),p(.)	269.40	1.10	3	0.3653

Table 2. – Most highly supported models for coyote (*Canis latran)* and raccoon (*Procyon lotor*) occupancy. $\psi\psi$ is an estimate of occupancy given site-specific covariates (canopy cover). p is the probability of detection given survey-specific covariates (baiting regime). K identifies the number of parameters utilized in each model. Models were selected utilizing the Akaike Information Criterion.

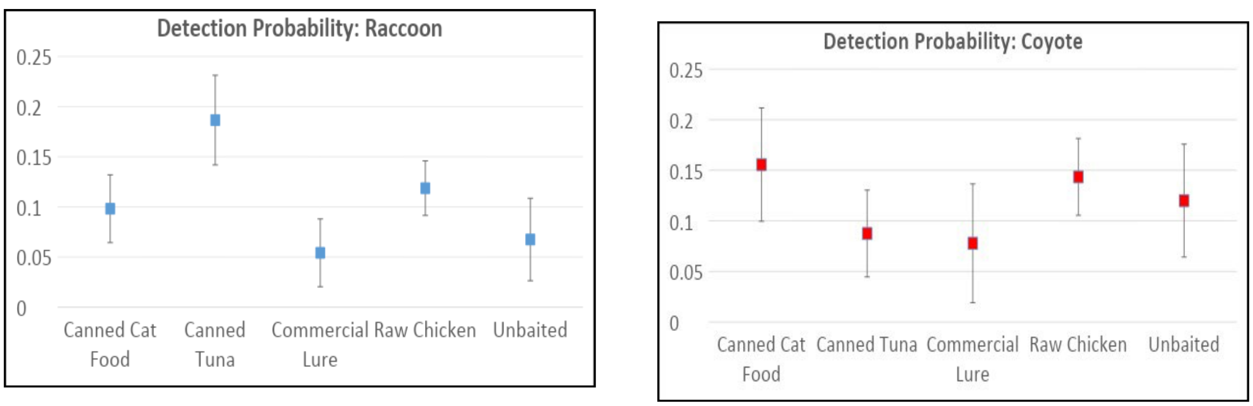

Fig. 5. - Detection probabilities with estimates of standard error according to baiting regime: Pontotoc Ridge Preserve, Oklahoma, May 2018 - September 2018. Canned tuna significantly impacted raccoon detection, however, bait appeared to have little impact upon detection for coyote

Discussion

Detection frequencies for all captured mesocarnivore species were expectedly low (Hoffman 1996; O'Connell et al. 2006) though it is unusual that only four mesocarnivore species were represented in the dataset. For this we offer a few potential explanations:

1. The data was limited to a 100-day collection period, the majority of which occurred in the summer season. With the data collected during this survey, it is not possible to examine how seasonal changes may have negatively impacted detection during this study. Similarly, a longer study period decreases the risk of false absence reporting (Gompper et al. 2006). Repeat surveys are needed to more accurately determine species diversity.
2. Ada, Oklahoma in Pontotoc County recorded 457 mm greater than average rainfall during the summer of 2018 (Oklahoma Climatological Survey 2019). Rapid vegetation growth repeatedly caused false activation in cameras. Some studies have reported a camera detection bias towards larger species as camera surveys rely upon motion activation. (Gompper et al. 2006). Vegetative growth in conjunction with this inherent bias may have resulted in undetected visits by individuals of a small species.
3. White-tailed deer and tick populations are of particular concern to managers within the preserve boundaries as limited culling has allowed both populations to spike. Although a direct link is uncertain, it is possible that increased parasitic activity has impacted the mesocarnivore presence within the preserve. Further research is necessary to explore the impact of this relationship in Pontotoc.

4. Feral hogs are notorious as destructive influences upon habitat and vegetation (Bevins et al. 2014). Despite management efforts to control feral hog populations, destructive rooting can be observed through the preserve and images of large groups were repeatedly collected at survey sites. Unknown are the direct or indirect impacts that the feral hog population may have upon native mesocarnivore species.

Canis latrans

Coyote constituted nearly 40% of all detections though their distribution was less widespread than that of raccoons. Coyote were detected at only 9/25 survey sites with a wide variation in canopy cover. The occupancy model with greatest support showed very little influence of canopy cover upon the occupancy of site by coyote. These results are not wholly unsurprising as coyote habitat and territorial ranges can vary greatly between individuals depending upon prey availability and potential risk (Crimmins, et al. 2012). Despite the limited number of cameras that detected coyote, images were collected from cameras that spanned the entire study area, indicating the potential for significant roaming behaviors within the preserve.

Baiting regime did not have any apparent impact upon the detection of coyote. We suggest that the lack of preference is the result of scavenging behavior that is common in coyote. Conversely, there is evidence to suggest that white-tailed deer constitute a significant portion of coyote diet (Boser 2009; Crimmins, et al. 2012). With the high population of white-tailed deer found within Pontotoc Ridge, resource availability for coyote is quite high. An increased resource availability potentially reduced the draw and impact of bait upon detection.

Procyon lotor

Raccoon was the most commonly observed species throughout the survey, constituting almost 60% of all detections. The majority of survey sites (17/25) reported at least one raccoon detection. Although some variation was observed, raccoon detections more commonly occurred at sites of higher canopy cover (Table 1) and thus detections were more likely in the western portion of the preserve where camera locations were strategically placed near or within a tree line. However, it is unclear whether this trend was entirely due to the abundance of canopy or simply due to the proximity of the cameras. As ecological generalist predators, raccoon select habitat based largely upon a balance of resource availability and risk of predation and are often observed traveling along edges, limiting excursions into open areas (Newbury and Thomas 2007). Our detections support this description as occupancy for individual raccoons was strongly associated with increased canopy cover.

Detection variables for raccoon are less clear. Baiting regime may have had some impact upon detection with raccoons appearing to favor canned tuna, consistent with other studies in which fish-based products have been successfully used as an attractant (Boulanger et al. 2008; Smyser et al. 2015). However, a model in which baiting regime did not impact detection also received significant support. Lack of baiting preference is consistent with the opportunistic generalist behaviors often associated with raccoon. However, with the potential for greater detection frequencies associated with canned tuna, further research is necessary to see if increased detections of raccoon are in fact associated with the use of canned tuna.

Didelphis virginiana

Opossum were detected relatively infrequently throughout the survey period and were detected at only two camera sites (4,13) with heavy canopy cover (0.87, 0.92). Although other sites maintained similar canopy coverage, a multitude of factors that were not investigated in this study may have influenced the presence or absence of opossum. Factors including distance from a standing water source and plant species diversity should be examined to determine how these site-specific covariates influence opossum detections.

Lynx rufus

Only a single bobcat image was recorded throughout the entire survey period. Though important in that this capture indicates presence, lacking significantly greater detections, little analysis could be conducted. Thornton et al. (2004) found that the presence of coyote did not appear to interfere significantly in the territorial ranges of bobcat so it is unlikely that this interaction is limiting bobcat presence within the preserve. In contrast, feral hogs are extremely destructive to ecosystems and are capable of directly disrupting trophic level interactions (Bevins et al. 2014). It is unclear precisely how this disruption may be impacting the presence of mesocarnivores within the preserve. However, it is most likely that due to the highly elusive nature of bobcat, sampling efforts were simply not sufficient to establish an accurate detection history for the species.

Mephitis mephitis

Despite the generalist tendencies, well-established Oklahoma populations, and the apparent abundance of suitable habitat within the preserve, striped skunk were not detected during this survey (Baldwin et al. 2004; Halloran and Glass 1959; Lewis 1972; Schnell and Grzybowski 1985). For this we offer several possible explanations:

1. It is quite probable that site variation was not great enough and that striped skunk ranges within the preserve did not overlap with camera site locations.
2. Although bait regimes were chosen according to recommendations put forth in Schlexer 2008, it is possible that attractants employed during this survey were not effective lures for striped skunk.
3. Overall, the survey length was relatively short. A greater timeline of survey data would likely produce striped skunk detections.

Future Research

Repeat surveys are necessary to determine the full diversity of mesocarnivore species present within the boundaries of the preserve. Multiple surveys may also provide further support for canopy-reliant models in raccoon occupancy and bait-specific increases in detection. Similarly, increased survey data may indicate more specific habitat variances that affect coyote occupancy and may also provide evidence for a baiting regime that is more effective in attracting coyote. Cross species investigation should also be conducted to determine the long-term impact that the white-tailed deer, tick, and feral hog populations may have upon the mesocarnivores within the preserve.

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Chapter 2: Assessing the Effect of Argumentation upon Student Content Knowledge and Perception of Science in a Middle School Science Classroom

Aaron E. Kidd

University of Central Oklahoma

INTRODUCTION

Historical Context of Modern Science Education

A variety of historical factors have contributed to modern education reform efforts in the United States. Widely criticized for its inability to meet the expectations of its critics, the American education story is often described as one of abject failure. Most research identifies two primary sources of this commonly-accepted narrative: international competition between the United States and the Soviet Union, culminating in the Cold War, and the 1983 *A Nation at Risk* report. (Johanningmeier, 2010; Suter & Camilli, 2019).

Concerns regarding the sustainability of US global dominance bloomed as WWII faded to a close. Post-war relations between the United States and the Soviet Union were already poor, but deteriorated rapidly after both nations failed to reach an agreement regarding the use and production of nuclear weapons. Despite U.S. objections, it quickly became apparent that the U.S.S.R. was interested in obtaining global standing as a nuclear powerhouse (Mcdougall, 2000). Scientific innovation and the deployment of nuclear weapons had ended the second world war, and thus it was to science that leaders in both countries looked in order to maintain their competitive standing (Oreskes, 2014). Desperate for a means to counteract global U.S. hydrogen bomb supremacy, U.S.S.R. scientists spent a period immediately following the war studying and modifying German-engineered V-2 rocketry into transports capable of delivering Soviet nuclear payloads. And, it was during this period of intensive engineering efforts that Soviet leadership also set sights on the development of an artificial data-gathering satellite. The construction of the R-7 rocket, a vehicle powerful enough to put an object into orbit, made this national goal a possibility. Initially, plans were to launch a comparatively advanced satellite equipped with an array of scientific measurement tools. However, fears that American engineers would succeed in launching their own satellite first, and delays caused by the excessive payload weight, Soviet leadership called for funding of a much simpler program; one that carried only a single radio transmitter: Sputnik 1 (Sagdeev, 2007).

The successful launch of Sputnik 1 unleashed an aura of fearful awe upon the American people that such a massive leap in technological advancement had the potential to produce. As the first man-made object orbited the globe, delusions of U.S. technological superiority were shattered. Lacking its own space-bound vehicle, the United States had an apparent vulnerability, and alarm amongst its citizens surged. U.S. policy leaders were relatively quick to react; establishing NASA in 1958 and endorsing the Apollo program in 1961 (Froschauer, 2006; Mather, 2007). Demands for a scientifically literate populace in order to remain competitive followed suit. Despite government action, U.S. anxiety regarding the viability of its own education programs in combating their soviet rivals had already been brought to the forefront.

Then, in 1983, conclusions from *A Nation at Risk* acted as a shot of adrenaline into national conversation and as a final nail in the coffin in the minds of education critics. The American education system appeared to be failing. Commissioned by the Reagan administration, the report, published by the National Commission on Excellence in Education, provided convincing evidence to the American public that U.S. students were falling behind in international competitiveness. SAT scores were found to have declined in the verbal and mathematics sections by 45 and 23 percent respectively, and international comparative test scores indicated a general decline of academics in the United States (Holton, 1984). Unimpressive national rankings seemed to be the norm for American students and it was on this basis that the Commission argued for sweeping changes in the American education complex in order to maintain U.S. global dominance (Johanningmeier, 2010). Regardless of its perceived purpose, the primary focus of the report was almost certainly economic rather than educational (Holton, 1984; Johanningmeier, 2010; Meadows, 2007). Because education disproportionately impacts key aspects of the American economic system, it was seen as an ideal instrument through which to fortify U.S. economic dominance.

A key and certainly prophetic component of *A Nation at Risk* was an assertion that employment opportunities were unlikely to remain stagnant in their 1980's form. With the arrival of computers, low-skilled work was predicted to decline, to be quickly replaced by more technologically demanding careers. In order to remain stably employed, future American workers would therefore require job skills beyond what a traditional education could potentially provide. Thus, a more robust knowledge framework would be necessary on which to build future job-related skills (Holton, 1984).

If the Cold War was kindling in the fire of education reform, *A Nation at Risk* was the source of its ignition. The sense of urgency produced by the report resulted in a slew of educational reforms and firmly planted education in the world of political discourse. In response, the mid 1980's saw more state-produced education legislation within just a few years than the states had enacted in nearly two decades (McIntush, 2000). It was from these roots that science education reforms materialized, to be capped with the most contemporary of interventions: the Next Generation Science Standards.

A Framework for K-12 Science Education

In 2010, the Carnegie Corporation and the Institute for Advanced Study, observing the progress of other subject areas, saw a unique opportunity to ameliorate American science education. A robust inter-state set of science standards were to be developed via a multi-step approach. First, the National Research Council was tasked with the construction of a standards framework (A Framework for K-12 Science Education). Primarily, the framework was to establish a scientific background upon which to construct the new standards. Manufactured by a committee of eighteen experts with representatives from a variety of scientific fields, the Framework for K-12 Science Education was released in July of 2011 (The National Academies Press, 2012; The Next Generation Science Standards, n.d).

Following the introduction of the Framework for K-12 Science and Engineering in 2012, education saw impassioned attempts to shift science standards nationally into a more rigorous and data-driven standing (Bulgren, Ellis, and Marquis, 2014). The modern desire to move from traditional instructional methodology to a more extensive and comprehensive science education is due largely to this Framework's assertion that previous science standards were insufficient in their ability to develop scientifically literate students. These standards, according to the Framework development team, were lacking greater coherence, resulting in a science education that was significantly scattered, and unintentionally instructed students at a level that was often a "mile long and an inch deep" (NRC, 2012). Two central goals were selected during the development of the Framework for K-12 Science and Engineering Education: (1) all students should be "educat[ed] in science and engineering" and (2) "future scientists, engineers, technologists, and technicians" should be provided a "foundational knowledge" from which to base their future science education (NRC, 2012).

Construction of the Framework for K-12 Science Education relied heavily upon modern educational pedagogy and a thorough understanding of how children learn. Key aspects of the Framework's development were generated based upon the following premises:

- Children naturally engage in scientific exploration.
- Greater scientific understanding requires a focus upon core concepts.
- Scientific knowledge develops over a period of time.
- Science is not simply a body of knowledge, but is also a practice.
- Classroom science should engage students at a personal level.
- Equity in science education requires universally rigorous standards.

The principles identified above form the basis for the core of the K-12 Framework: the three dimensions of science education (The National Academies Press, 2012; The Next Generation Science Standards, n.d).

The Framework for K-12 Science Education was developed as a set of three distinct dimensions: Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas (Bybee, 2014; Fig. 6). The dimensions are designed to work as a cohesive unit through which students develop a comprehensive understanding of science through realistic experiences modified for the classroom (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014). The Scientific and Engineering Practices, as a dimension, is comprised of tasks that are thought to define science itself (modeling, data interpretation, engineering, argumentation, etc.). Crosscutting concepts are processes that bridge scientific disciplines and include the identification of patterns, cause and effect, and the use of scale and proportion. Finally, Disciplinary Core Ideas are what is typically considered in a scientific curriculum: subject-specific content. This includes disciplines such as biology, chemistry, and the physical sciences (NRC, 2012).

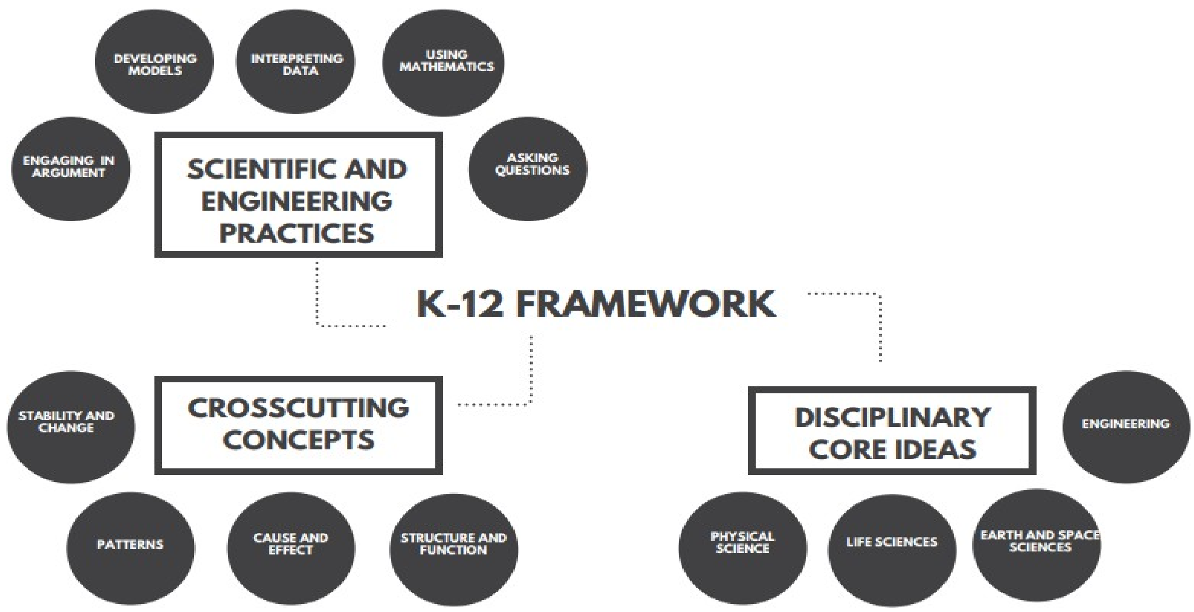


Fig. 6: Three dimensions of the K-12 Framework for Science Education including Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. (Adapted from NRC, 2012)

The Next Generation Science Standards

The Framework for K-12 Science Education functioned as a vision for the future of science education within the United States and from this influential first step, emerged a document of more practical use: The Next Generation Science Standards (NGSS). A partnered effort of twenty-six states and the Achieve organization, the NGSS was the result of forty individual authors, chosen from states across the country. K-12 educators, university professors, and researchers were selected based upon specific expertise through an intensive application process in hopes of extending the usefulness of the standards to a range of diverse classroom settings (Pruitt, 2014).

Released in 2014, the NGSS retain the dimensions that were outlined in the Framework. Each standard identifies the most relevant of Science and Engineering practices, Disciplinary Core Ideas, and Crosscutting Concepts, specific to the topic of study. Yet, unlike the Framework, the NGSS are designed to act as a working document in curriculum development. Therefore, each standard also contains a set of performance expectations from which instructors can generate assessments of student progress. Performance expectations intentionally utilize a verbiage that emphasizes student actions such as “conduct”, “investigate”, and “plan” (Veal & Sneed, 2014). This wording is, by design, an attempt to redefine classroom science experiences into those deemed necessary in The Framework for K-12 Science Education.

Misconceptions and Student Learning:

Instrumental in the development of the three dimensions was the proposition that students do not arrive in the science classroom without experience engaging in scientific exploration. Rather, most students have spent a good portion of their childhood unwittingly performing science of their own sort; asking questions and generating their own hypotheses as they navigate the world (Tanner & Allen, 2005). Childhood scientific investigation may produce misconceptions: explanations that while effective in context-specific scenarios, collapse when expanded to broader scientific concepts (Gomez-Zwiep 2008). Inaccurate reasoning is often reinforced at home and in ineffectual classroom environments. So, when new information, presented in the classroom, clashes with these early experiences, misconceptions can act as a strong deterrent to learning (Tawde, Boccio, & Kolack, 2017). Though the education literature decries the negative impact of misconceptions upon learning, there is some disagreement regarding the most effective means to reduce their effect. (Gomez-Zwiep, 2008; Miller, 2013).

Measuring the Effectiveness of the K-12 Framework and the NGSS

Since their arrival, the NGSS have been a subject of significant study. Much of the work, however, has focused upon pre-service educators, current teacher perceptions, and implementation strategies. Some studies have addressed the effectiveness of the scientific practices. For example, curricular emphasis on the engineering practices of the Framework has produced observably positive results in a wide range of classroom settings; generating greater student engagement, interest in engineering, and achievement (Guzey, Harwell, Moreno, Peralta, & Moore, 2017; Wendell & Rogers, 2013). Argumentation as a classroom scientific practice has received somewhat less attention in the research literature, though multiple proposed models for classroom implementation can be found (Chin & Osbourne, 2010; Sampson & Gleim, 2009; Sadler, 2006; Bulgren, Ellis, & Marquis 2014; Walker, Sampson, Grooms, Anderson & Zimmerman, 2012). Most models have seen testing in upper secondary grades and at the collegiate level. Little work however, has been conducted to test the effectiveness of such models within the confines of the middle school science classroom.

Argument is a critical component of the scientific process in which individuals utilize higher-order thinking in order to understand and provide empirical evidence, reach conclusions from a set of data, and weigh the validity of counterarguments (Bulgren, Ellis, & Marquis, 2014; Sampson & Gleim, 2009). Educators often find this particular component of science difficult to accurately recreate within their classrooms (Sampson & Grooms, 2010). Due to its effectiveness in increasing student understanding and scientific literacy, scientific writing is often the primary motif through which argument is integrated into classroom experiences and, it is through argument that classroom misconceptions can be effectively revealed and addressed (Cetin & Seda, 2017). However, written argumentation requires significant turnover time as in this format, the instructor must independently examine each student or group of students' responses to provide feedback. More robust models of argumentation, such as those expressed in Sampson & Grooms, (2010), and Walker, Sampson, Grooms, Anderson, Zimmerman, (2012) similarly require significant time investments that are likely not possible in all science classrooms.

Research Goals:

The Framework for K-12 Science Education in conjunction with the NGSS are the most recent attempts to address the concerns of American scientific literacy within the public education system. As identified within the Framework, science education is most effective when students address misconceptions through active engagement in practices that mirror the scientific process. These practices include engaging in argument, developing models, and engineering amongst others (NRC, 2012). Although some work has been produced that examines the effect of emphasizing the argumentation component of The Framework, much of this research has been conducted outside the middle school classroom. Beyond this, the models of implementation produced by these studies are often overly cumbersome and therefore difficult to implement into a typical classroom environment (Sampson & Gleim, 2009; Sampson & Grooms, 2010; Sadler, 2006; Bulgren, Ellis, and Marquis 2014).

Based upon the problems outlined, four goals were developed for this project:

1. Determine whether an emphasis upon naïve classroom argumentation improves student content knowledge growth.
2. Develop and employ a simplified model of classroom argumentation for ease of integration into current curriculum.
3. Determine the impact of argumentation upon student perception of science.

METHODS

Recruitment

During the 2019 spring semester, 151 research participants were recruited from a team of 163 7th grade students. Following IRB approval, students returned signed parental-permission forms indicating willingness to participate in the project. Prior to the project, potential participants were informed that regardless of participation, underpinning curriculum and student grades would not be impacted. Although non-participants completed each activity within the research, data from these students was not collected.

Recruitment took place at Deer Creek Middle School within the Deer Creek School District. Deer Creek Middle School is located in north-central Oklahoma, in the city of Edmond and is comprised of households averaging a yearly income of $63,536. This value exceeds the state average of $49,742. Although the district is expanding rapidly, the current racial make-up of the district is largely homogenous with 70.9% of students identifying as caucasian (OEQA, 2017).

Curriculum Description

Curriculum units were purchased by the Deer Creek school district and were designed and organized by SEPUP (Science Education for Public Understanding Program). A branch of UC Berkeley's Lawrence Hall of Science, SEPUP develops curriculum based upon the guidelines provided by the NGSS. The curriculum integrates student investigation and real-world problem exploration to teach scientific content (Lawrence Hall of Science, 2019). With the exception of additional argumentation sessions, treatment and control subunits employed in this study followed the predesigned format provided by SEPUP curriculum team.

Two units were selected prior to beginning the study: Space and Weather-Climate. The units were further divided into five distinct subunits by natural break points in material and assigned an identifier based upon the major topic of study. The subunits selected included: The Moon's Phases, Objects in Space, Gravity, Earth's Seasons, and Local Weather. Subunits were divided into "Argumentation" and "Non-Argumentation" control and treatment categories. Treatment/control selection was randomly assigned for the first subunit (The Moon's Phases) and all following subunits were assigned a category in a 1 - 2 - 1 - 1 design determined by curricular time constraints (Fig. 7).

Fig. 7: Argumentation and non-argumentation subunits organized in sequential order beginning with The Moon's Phases and ending with a unit study of Local Weather.

Argumentation Session Design

Argumentation sessions were designed following a basic pre-determined framework.

- Sessions would occur during one 50-minute class period.
- Fifteen minutes were provided for group planning and discussion.
- Argumentation sessions would be student-led.
- Participant expectations would be strictly enforced.

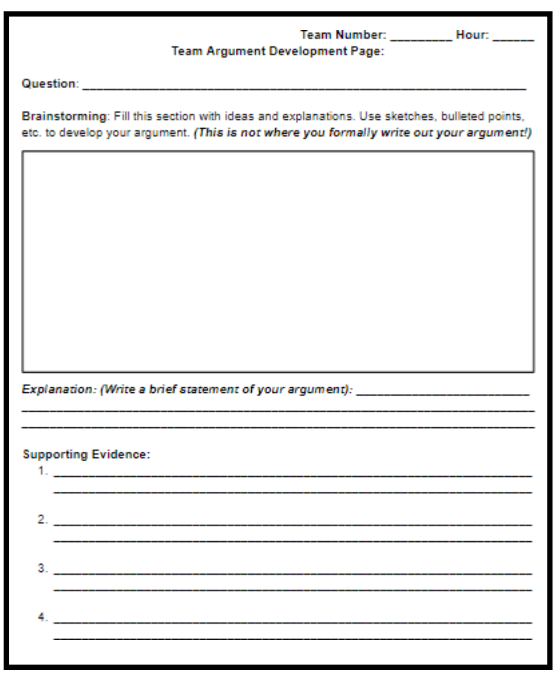
At the start of each treatment subunit, student participants were presented with a subject-related phenomenon to explore. Phenomena were selected based upon potential student interest, relatedness to unit topics, ease of argument development, and potential for exposing misconceptions. Examples of debate topics include: "Why does the moon change shape?", "Why are African Elephants losing their tusks?", and "What is gravity?". Student groups were provided an argumentation planning page (Fig. 3) and given fifteen minutes to develop an explanation with supporting evidence. Students were encouraged to model their explanations through sketches, written responses, and graphical representations. During the planning component of the session, instructor-guided questioning was utilized in an attempt to assist groups in identifying potential weaknesses in their argument and to foster deeper thinking about the assigned phenomenon.

Concluding the argument development stage, student participants were reminded of the argumentation session expectations: speaking is turn-based, sessions are student-led, and respect for other groups' ideas is required. Each student group was given an opportunity to present their proposed explanation for the presented phenomenon. Students were given free use of the whiteboard, classroom models, etc. to present their models. Following each presentation, classmates were encouraged to question and find fault in each proposed explanation. Discussion ensued until either a class-wide consensus was reached or debate stagnated.

Measurement Tools

Prior to investigation, formative and summative assessments were designed for each subunit. Assessments were constructed based upon the following framework:

- Eight questions that accurately assess unit-specific learning goals.
- 15-25% DOK question level 1
- 55-65% DOK question level 2
- 15-25% DOK question level 3



Team Number: ________ Hour: ______

Team Argument Development Page:

Question: ____

Brainstorming: Fill this section with ideas and explanations. Use sketches, bulleted points, etc. to develop your argument. *(This is not where you formally write out your argument!)*

Explanation: (Write a brief statement of your argument): ______________________

Supporting Evidence:

1. ____
2. ____
3. ____
4. ____

Fig. 8: Student argument development page in which students generate models prior to an argumentation session.

In order to regularly measure participant perception of science education, a student survey was employed alongside the formative and summative assessments. Survey design was adapted from (Summers & Abd-El-Kahlic, 2018). Survey length was limited to fifteen questions and questions attempted to measure overall interest in science, interest in future science careers, and the perceived importance of scientific knowledge.

All data was gathered and collected via ZipGrade, a classroom assessment-grading tool. Students responded to survey and assessment questions on the company-provided answer sheets and participant results were scored through the program.

Following the conclusion of the final subunit, fifteen students were randomly selected from three randomly selected classes. Representatives from both honors and standard classes were present. Students were asked to verbally respond to a list of five open-ended questions in order to gauge the general opinion regarding the argumentation sessions. Examples of polling questions included: “Do you think that argument day benefits you?”, “What would you change about argument day?”, and “Do you enjoy argument day?”. Responses were recorded and stored alongside other collected data.

Study Design

An initial student-perception survey measurement was taken prior to data collection. Then, following the schedule outlined in Figure 7, participants completed a formative assessment prior to beginning both treatment and control units. Formative assessment results were collected and recorded. Participants were not privy to formative assessment scores and discussion of assessment results was prohibited within the confines of the classroom. In treatment subunits, students participated in an argumentation session at the beginning of the subunit. These sessions occurred within one week of the start of the unit. However, there was some discrepancy in argument session timing due to unforeseen interruptions. Control units followed the predesigned format of the SEPUP curriculum without the addition of argumentation sessions. Signaling the conclusion of each subunit, research participants once again completed the topic-specific assessment. Perception surveys were also re-administered at the conclusion of each subunit. Formative, summative, and perception survey data was collected and stored physically in a secured filing cabinet and digitally on a district-monitored laptop (Fig. 9).

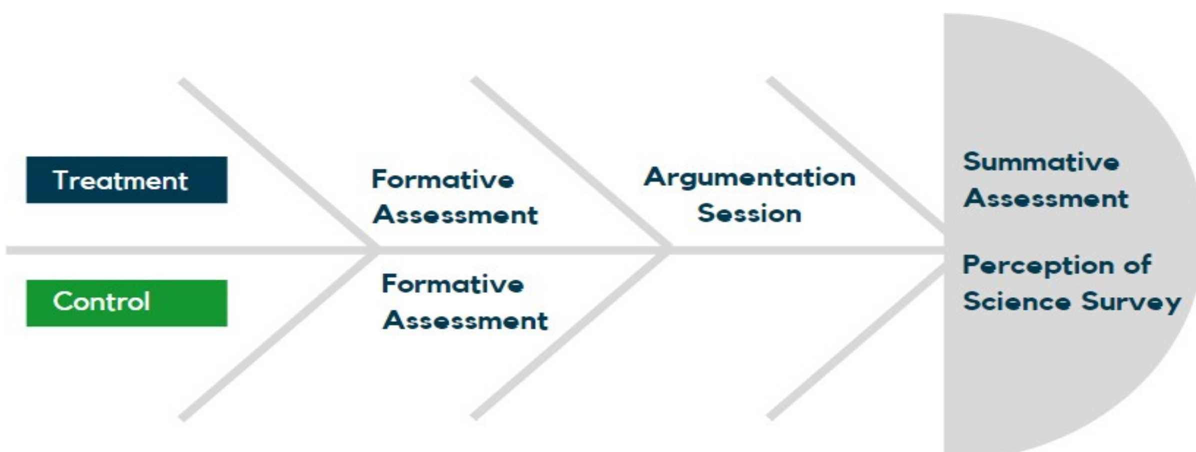
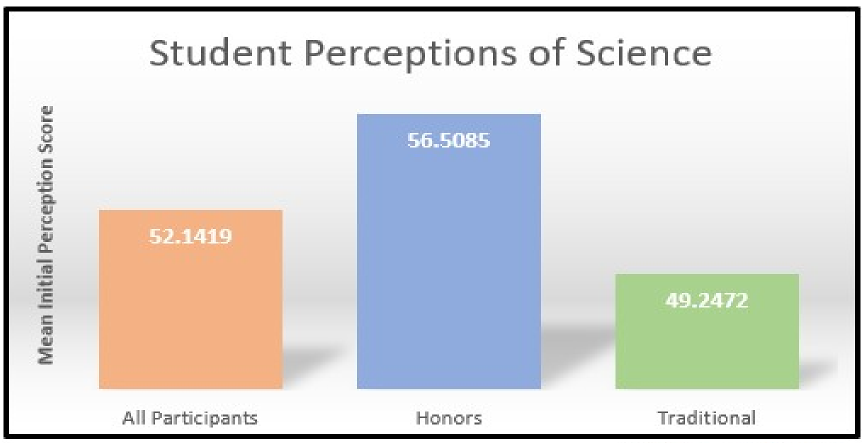


Fig. 9: Subunit design structure in which each subunit began with a formative assessment, proceeded with curriculum-determined lesson plans, and ended with a summative assessment alongside a student perception of science survey.

RESULTS

Student perceptions of science were generally positive with a mean score of 52.142 out of a possible 75 points. Results of a Mann-Whitney U Test indicated baseline mean scores that differed significantly between honors and traditional path students ($U = 1350.5$, $p < .0001$). Honors students generally reported a higher personal interest in science than their traditional-path peers with mean scores of 56.509 and 49.247 respectively (Fig. 10). Unit treatment had no significant effect upon student perception of science with mean scores revealing negligible differences between treatment and control subunits (Table 3).



			Statistic	Std. Error
InitialSurvey	Mean		52.1419	.84586
	95% Confidence Interval for Mean	Lower Bound	50.4703	
		Upper Bound	53.8135	

			Statistic	Std. Error
InitialPreAP	Mean		56.5085	1.10611
	95% Confidence Interval for Mean	Lower Bound	54.2944	
		Upper Bound	58.7226	

			Statistic	Std. Error
InitialReg	Mean		49.2472	1.10185
	95% Confidence Interval for Mean	Lower Bound	47.0575	
		Upper Bound	51.4369	

Fig. 10: Initial perception score comparison between honors ($N = 54$) and traditional ($N = 87$) student groups with honors students ranking science significantly higher than traditional path students Mann-Whitney U Test: ($U = 1350.5$, $p < .0001$).

	N	Mean	Minimum	Maximum
Argumentation	288	52.572	15.00	75.00
Non-Argumentation	429	52.455	15.00	75.00

Table 3: Comparison of student perception of science following treatment and control units. Minimal difference in mean scores indicate little to no impact of unit type upon student perception of science.

Generally, the mean of pre-assessment scores differed between control and treatment subunits with argumentation subunits generally presenting an overall lower score. (Table 4) Subunits implementing argumentation sessions also produced lower Post-assessment scores (Table 4). However, a Mixed-design ANOVA indicated no significant difference at $p<.05$ in student knowledge growth between treatment and control subunits [$F(1,1) = 3.474$, $p = .063$] (Fig. 6A).

Analysis of Non-honors and Honors students separately generated conflicting results. Mean Pre-assessment scores differed significantly between control (5.105) and treatment units (4.396) in honors classes ($U=6760$, $p<.0001$). Mean Pre-assessment scores for non-honors classes did not differ significantly between control (4.06) and treatment units (3.94) ($U=20682$, $p=.477$) (Table 5). Mean Post-assessment scores for honors students did not differ significantly between treatment and control units ($U=9359.5$, $p=.0601$). Mean Post-assessment scores for Non-honors classes similarly did not differ significantly between treatment and control units ($U=23329$, $p=.363$) (Table 5) Separation of honors and traditional path students, however, did identify Mixed-design ANOVA results in which there was a significant difference at $p<.05$ in learning growth between treatment and control groups in honors courses [$F(1,1) = 7.508$, $p = .007$] (Fig. 6B).

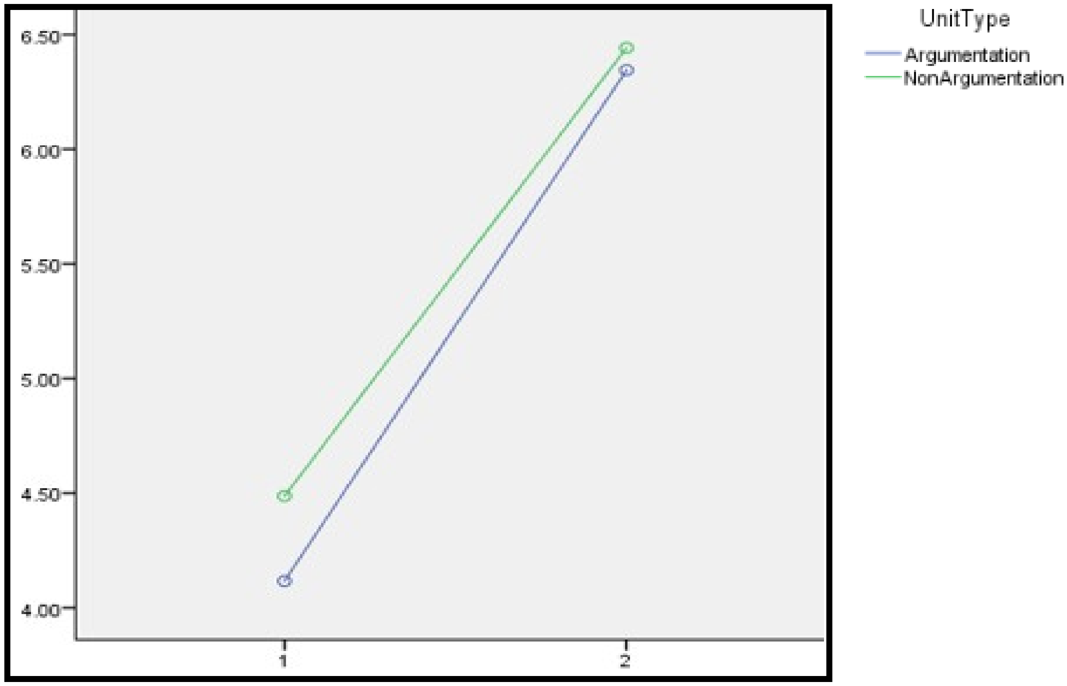
	Unit Type	Mean	Std. Deviation	N
Pre-Assessment	Argument	4.12	1.38	284
	Non-Argument	4.49	1.41	421
Post-Assessment	Argument	6.35	1.38	284
	Non-argument	6.44	1.48	421

Table 4: Comparison of pre and post-assessments for treatment and control subunits. Pre and post-assessment scores were higher for control units in which argumentation sessions were not implemented.

Class Level	Unit Type	Pre-Assessment Mean	Post-Assessment Mean
Honors	Argument	4.39, SD=1.641	6.97, SD=0.822
Non-honors	Argument	3.94, SD=2.002	5.84, SD=2.326
Honors	Nonargument	5.11, SD=1.721	7.15, SD=0.923
Non-honors	Nonargument	4.06, SD=1.755	5.96, SD=2.526

Table 5: Comparison of pre and post-assessments organized designated by class type (honors and non-honors) for both treatment and control units.

A.



B.

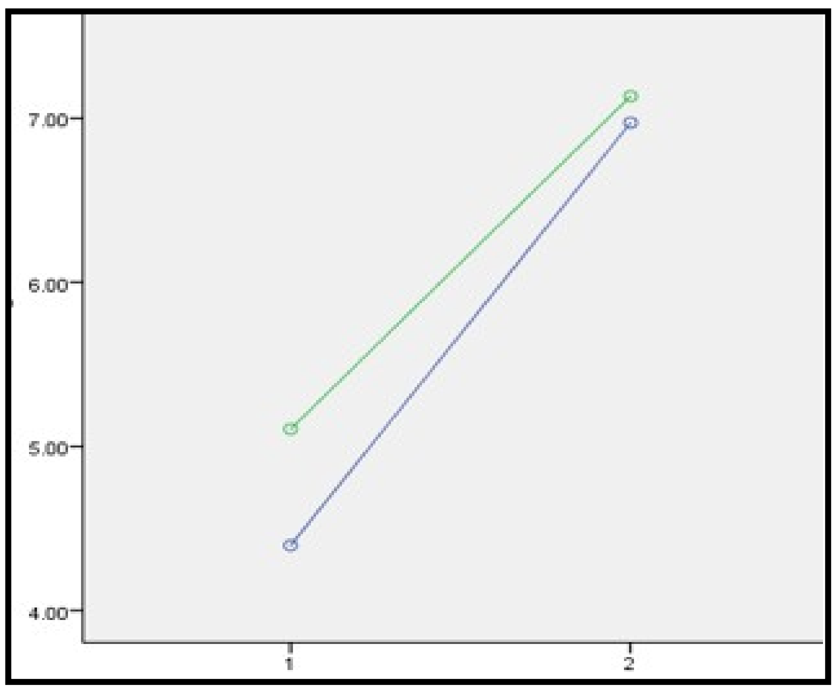


Fig. 11: Graphical representation of student learning growth between time 1 (pre-assessment) and time 2 (post-assessment). Figure 11A displays average growth for both honors and traditional path students with no significant difference between treatment and control subunits. Figure 11B indicates a significant difference in growth for honors students during treatment subunits. [F (1,1) = 7.508, p = .007].

DISCUSSION

Modern interest in reformation of scientific curriculum is driven largely by social and economic factors dating back to the Second World War (Johanningmeier, 2010; Suter & Camilli, 2019). Concerns about the burgeoning need for a scientifically literate populace in combination with desires to maintain global industrial dominance ultimately culminated in the construction of the current science standards. The NGSS, developed from The Framework for K-12 Science Education outlined a science education in which American students would gain a working knowledge of science through realistic application of its practices within the classroom (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014).

Argumentation is one of the core components of the scientific practices outlined in the NGSS (NRC, 2012). Through classroom argumentation, students develop, test, and debate the merits of hypotheses with the end goal of generating explanations that more accurately align with those accepted within the scientific community. Argumentation is thought to be a necessary step in critical thinking (Chin & Osbourne, 2010) and likely contributes to the elimination of misconceptions about science (Cetin & Seda, 2017). In this project, we sought to explore the effectiveness of including simplified argumentation activities in which students developed naïve models to phenomenon-based questions and exposed them to peer-evaluation upon student content knowledge and overall perceptions of science.

Content Knowledge Growth

Inserting a verbal argumentation activity into the middle school science curriculum generated mixed results in content knowledge growth. Contrasting somewhat the results of

Bulgren, Ellis, & Marquis, 2014, significant differences in learning between control and treatment units were detected only in Honors level courses. Though both groups of students displayed significantly increased content knowledge between pre and post-assessments, content knowledge growth for Non-honors students was essentially equal between treatment and control units. Thus, the additional intervention strategy of argumentation appeared to have little to no effect upon Non-honors participants despite their lower initial pre-test scores and therefore greater potential to produce significant outcomes. It is important to note however, that in Non-honors classes, where a significant difference in learning growth was not detected, student learning continued to occur regardless of treatment. In these classes, there was no significant difference in pre-test or post-test scores between unit type detected, indicating that argumentation sessions had no negative impact upon student learning.

Two of the four Non-honors courses generated conflicting results with the overall average of the Non-honors subgroup. One class of medium size (approximately twenty-six students) generated significantly positive outcomes when argumentation strategies were employed. However, unlike other Non-honors and Honors classes that saw nearly a 100% participation rate, six of the total twenty-six students declined participation in the study. Of these six students, the majority were generally lower-performing students with a documented disability who wished not to be included in the research. This voluntary removal almost certainly impacted the overall average scores of the participants, likely skewing the outcome. The removal of these students resulted in a class composition that more closely resembled that of an honors course than that of a Non-honors class.

In addition, a relatively small class of approximately sixteen students actually reported negative results from the inclusion of argumentation into curriculum. In this classroom, growth during treatment units appears to have been hampered by argumentation sessions. This result may have been due to student discomfort with verbal presentation in front of their peers. Discussion was difficult to initiate within this class and required significant instructor intervention as conversation regularly stalled with little in-depth thought. Thus, it is likely that in this classroom, verbal argumentation as an instructional strategy was not effectively providing students the opportunity to develop their topic-specific models.

Student Perception of Science

Participation in argument development produced no significant difference in student perception of science between treatment and control units. These results were consistent between both Honors and Non-honors classes. Unlike Walker et al. 2012 (where a much more intensive form of argumentation was employed) it is possible and quite likely that the implementation of a single activity into each unit was insufficient in significantly altering a student's perception of science as a subject.

The success of verbal argumentation as an instructional tool however, does appear to align with the average rating that classes assigned science during the perception survey. Honors classes reported statistically higher scores on the perception of science survey than scores reported by their Non-honors peers. Conversely, classes in which treatment learning growth was greatest similarly reported high scores on the perception of science survey. These classes generally fostered debate independent of instructor intrusion. Students within these classes were typically more willing to present and discuss topics with their peers and thus required very little oversight. This is not necessarily to suggest that argumentation is an ineffective means through which to instruct students with a comparatively low interest in the field of science. Instead it is likely that student engagement (generally a result of interest) is a key factor in the success or failure of verbal argumentation. Greater effort is almost certainly necessary to foster engagement within Non-honors classrooms where science is not of high interest. The methods employed in this study were likely insufficient in peaking the interest of Non-honors students resulting in an instructional strategy that did not produce a measurably positive outcome.

Future Research

A primary goal of this project was to determine whether a simplified form of argumentation as an instructional strategy could effectively increase student content knowledge. Towards this goal, our model produced mixed results. Positive results were detected for Honors students but Non-honors students saw little to no difference in learning outcomes. Future research will need to consider whether a greater emphasis upon argumentation (a process requiring more than a single day of implementation) may produce the desired results in Non-honors classes that were not detected in this study. Further research should also consider whether argumentation is equally effective for all groups of students, including those from underrepresented groups.

The Student Perception of Science survey indicated little to no difference in treatment and control units in swaying student opinion. Much like content knowledge gains for Non-honors students, it is unlikely that a single intervention is capable of drastically altering a student's perception of science as a field of study. Therefore, future research will need to conduct a measurement following a more intensive integration of argumentation into currently curriculum to determine whether a greater emphasis is capable of impacting a student's perception.

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CONCLUSION

Since the introduction of The Framework for K-12 Science Education, a national shift towards a more comprehensive science education has become a unifying goal amongst science education professionals and stakeholders. Within this vision for science education in the United States, multiple key assumptions are made regarding the most effective means through which science is taught within a classroom. Primary amongst these assumptions is the observation that students must actively participate in scientific investigation in order to fully comprehend the complexities of the scientific process. Further, it is upon this assumption that this particular thesis project was constructed - In order for a graduate full-time public-school teacher to truly replicate scientific practices in their classroom, they must utilize some first-hand experience of the scientific practices.

During the biological research component of this project, I gained experience in many areas that during my undergraduate courses had been sorely overlooked: hypothesis development, research design, literature review, statistical modeling, and data analysis. Much of the theoretical components of science that had been engrained into my thinking during my undergraduate experiences (the constant changing nature of science, the importance of research-backed reasoning, etc.) withstood the experience and held true throughout. However, without actively pursuing a research goal, the complexity and importance of these founding principles of science would not have been fully realized. Although for many years I had been exposed in small snippets to the investigative nature of science, it was not until I had truly immersed myself within the process and experienced the complexities within that I was truly able to grasp the scientific process.

Following my biological research project, my perspective regarding the integration of scientific practices within my own classroom shifted considerably. Although much of the science content that was used within my classroom relied heavily upon investigation and experience, little of these lessons truly replicated scientific practices. For example, although my students were often required to produce some form of report following an investigation, little time was spent analyzing their conclusions amongst their peers. So, regardless of whether their conclusions were sound, little time was spent developing a consensus.

The purpose of this project was essentially two-fold. In order to integrate realistic scientific practices into my classroom and thus measure their effectiveness, I would need to gain first-hand experience in scientific research. Then, following this experience, I would attempt to recreate a small component of this experience into my science classroom and measure the effectiveness in teaching scientific content. From this process. and the analysis conducted following my classroom research, it is apparent that the integration of scientific practices seems to be a promising area of research in science education. Although, it is important to note that significant work must be done in order to pinpoint the most effective means through which this can be incorporated into most K-12 science classrooms.

Signature: Elizabeth Allan

Email: eallan@uco.edu

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