Science Education Through Creative Writing: A Case Study Using Entomology

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Abstract

Science and art are intrinsically linked. Science requires curiosity, along with skills in observation, problem-solving, and critical thinking. Art is no different; however, the two disciplines are typically presented as opposites to children at a young age and the emphasis on differences lead to a false dichotomy of career paths and even self-identification. Recent research has shown that integrating artistic disciplines such as creative writing into traditional STEM fields aids both majors and non-majors in establishing interdisciplinary connections between required education courses and courses in their field of interest, resulting in increased student learning and understanding. This study incorporated creative writing into a college-level entomology course through writing prompts where students observed magnified images of arthropods and other objects and described them using creative language. The students were also encouraged to engage with the course material through personal experiences and reflections. We discovered that this creative writing assignment helped students gain confidence in their writing abilities, foster new connections through critical thinking, and develop a deeper appreciation for entomology. In addition, this exercise helps instructors identify student's misconceptions, establish baseline class knowledge, and connect facets of multiple disciplines to meet learning objectives.

Keywords: Creative Writing, Interdisciplinary, Pedagogy, Entomology, Multimodality

People generally fear what they do not know, and for many, insects and other arthropods are largely unknown. The avoidance of insects often starts at young age when children are taught that the crawling creatures in their backyard are "bad", "scary", "dangerous" or "gross"—

often with parents passing along misconceptions learned from their parents or peers. Further, arthropods such as insects and arachnids are often grouped under umbrella terms, such as "bug", ignoring fundamental differences in appearance and behavior. Although arthropods dominate terrestrial biodiversity, misconceptions about other small organisms—including worms and fungi—are also common, as are misconceptions about some larger organisms, including snakes (Golick et. al, 2021).

This may explain why many are reluctant to learn about arthropods and other organisms despite their critical positive roles in agriculture including: pollination, dung removal, and food webs. Insects also play large roles in disease transmission and crop loss. This dichotomy highlights the importance of entomological knowledge, and the need for curiosity, and engagement with the sciences. Instruction with insects, a requirement for deep understanding of their biology and behavior, is further challenged as many people have a learned fear and disgust of insects and related arthropods (Wagler & Wagler, 2018). Improving how professors of entomology and other disciplines might overcome the challenges of teaching non-majors in their field may lie in an entirely different field of study: creative writing.

The language arts and science are intrinsically linked. Both require skills in observation, curiosity, problem-solving, and critical thinking. Yet, the phenomenon of separating the two in academia is a standard—though a relatively new—practice. In the 1960s, neurobiologist Roger Sperry published results on his split-brain theory, showing that the left and right hemispheres of the brain were responsible for separate functions. His research concluded the right hemisphere of the brain dominated spatial and musical functions, while the left hemisphere was responsible for verbal and analytical tasks (Sperry, 1967). However, this dichotomy was misinterpreted by the public, leading to the false conclusion that people are either talented in math and science, or in language and arts—but rarely both—leading to the separation of art and science in academia (Tahir, 2021). Although it became more standard to think of the split, scientists historically quoted well-known poets in their textbooks, while famous novelists such as H.G Wells and Kafka relied heavily on knowledge of science and mathematics in their creative works (Otis, 2002). Further, some of the most renowned scientists, including Nikola Telsa, Benjamin Franklin, Da Vinci, Albert Einstien, and John James Audubon were celebrated for their artistic contributions and scientific writings (Stroud & Bains, 2019).

Creative forms of writing such as ekphrastics, poetry, fiction, and non-fiction have all been used to inform science writing through metaphorical devices, allegories, and imagery (Hildebrand, 1996). Watkins & Tehrani (2020) claim that "creative writing" has long been recognized as a dynamic platform for self-directed inquiry. As such, creative writing allows authors to embed scientific concepts in the situated realities of their characters or speakers, i.e., the physical, social, and technological contexts of their lived experience. In this way, authors have explored the implications of these scientific concepts and their interconnections with other ways of knowing." Creative writing also has the potential to enhance senses of wonder and curiosity (Harvey, 2002), which has been linked to an enhancement of critical analysis and self-directed research skills (Hadzigeorgiou, 2005).

Recently the integration of creative writing in STEM classes has shown to be successful across many disciplines. Krom and Williams (2012) used story-telling activities during instruction of accounting students and demonstrated increased student engagement and learning outcomes. Creative writing has also been used as an effective assessment tool in physics (Guilaran, 2012), chemistry (Henary, et al. 2015; Ostrom, et al. 2020) and proposed as a means to improve science understanding in biology (Gillen, et al. 2020), and agriculture sciences (Olien & Harper, 1994).

We proposed that a creative writing activity in an introductory entomology course would allow us to evaluate student bias and misconceptions about insects and would be an alternative method for students to share what they know about insects' visible and "hidden" biological traits (e.g. morphology, biology, and natural history). In the creative writing activity, students observed digital, macro images of insects and other arthropods, and described what they observed using creative language. We sought to engage student curiosity, observation, and critical thinking—tools which are necessary for long-term scientific learning. Additionally, we proposed that the artistic, low-risk aspects of creative writing would reduce anxieties about the performance of academic writing, resulting in greater attention to the learning objectives.

Methods

"Arthropod or Not" Activity

Students were instructed to engage with high-resolution, up-close images of insects/related arthropods (hereafter referred to as "insect") alongside other objects including flowers and eyes of vertebrates to determine which images were of arthropods, and which were not. The 35-slide PowerPoint used images sourced from Google. The slides alternated between macro-image photographs of insects and macro-image photographs of non-insect related objects—including an orange, eyes, a feather, and flowers. Each macro-image slide was followed by a slide which depicted a full view of the object, so students could identify if their guess was correct.

Students were given the instructions to write two 3-5 sentence paragraphs. In the first paragraph, they were instructed to use non-insect related words to describe an insect image from the slide set. In the second paragraph, students were instructed to use insect-related words to describe a non-insect image of their choice.

For example:

Paragraph 1 (describing the arthropod pictured)

"The jumping spider's legs twist like black bendy straws. Its eyes are wide and shiny like a camera lens. When the spider jumps, it skips like a stone over water. When the spider spins its web, it floats through the air like a dandelion seed."

Paragraph 2 (describing the object pictured)

"The feather shines emerald like a scarab-beetle shell. Up close, it looks like the antennae of a Luna moth. When a feather is dropped, it floats to the ground like a spider on a web."

The goal of this assignment was to encourage students to observe arthropods closely and reflect critically on their appearance while also thinking of how insects are described. Close observation is something many people are reluctant to do with live insects because of fear, negative biases, misconceptions, or all the above. By using photographs rather than live arthropods, we anticipated more students would be willing to engage with the activity. With the writing prompt, the outcome was to defamiliarize the preconceived ideas students might hold about the arthropods' appearance, such that they are all "slimy", "disturbing", "dangerous", or "disgusting," by having them compare arthropods to objects with which they are more familiar.

Insects and Society Honors Section

We first conducted this activity with an honors section of "Insects and Society" that had 10 students. Out of the 10 students, three were entomology majors. Our goal was to test and improve this activity before developing it into a graded assignment for the class of more than 300 students.

The honor's students were instructed to complete the "Arthropod or Not" activity outside of class, and then orally present their paragraphs to the class during the next session. After presenting, students were given an anonymous questionnaire which asked questions about the activity. The questions centered on their general experience, whether they gained a unique perspective from the activity, and how this assignment might help students who are not familiar/comfortable with the subject of entomology. Based on feedback from the students, we developed a full activity for the Spring, 2021 semester.

ENTO 2003: Insects and Society

In Spring, 2021, the "Arthropod or Not" Activity was assigned in the course "ENTO 2003: Insects and Society." 295 students were enrolled in this section, with the majority pursuing degrees in marketing, finance, and agricultural communications. From the 295 students, the average GPA was 3.05, and 20% were first generation college students. About 2/3rds (186) of students were from in-state. Females accounted for 46.4% (137) of the total student population and males 53.6% (158). Of the students, 36.2% (107) were registered as racial-minorities.

The activity was assigned and graded during the second week of the semester with students having the opportunity to attend or view the first five lectures of the course before the assignment was due. With approval from the Institutional Review Board (#22-129), a survey was administered approximately two months later in the semester, the students were asked to participate in an 18-question Likert-Scale survey about the activity, and compare it with other more traditional assignments in the class. The survey was made using Qualtrics (Qualtrics, Provo, UT) and administered through a link on the course management software, Canvas (Instructure, Inc). All student responses were anonymous. Students were encouraged to participate by earning 5 bonus points after completing the survey, which they documented by uploading a screenshot of the survey completion page via Canvas.

Students were asked to rank the statements in the survey from 1 to 5, with 1 representing 'strongly disagree', 2 representing 'disagree', 3 representing 'neutral', 4 representing 'agree', and 5 representing 'strongly agree'. The statements are as follows (Table 1):

Table 1: Likert-Survey Questions. Questions were administered anonymously, and students were incentivized by receiving extra credit.

The questions were designed to gain insight on whether the creative writing assignment helped students develop a deeper appreciation of the topic, gave them confidence in their ability to communicate the learning objectives, and led to a greater acquisition of knowledge. By comparing the "Arthropod or Not" activity to other assignments in the course, we tested whether the "genre" of assignments, (e.g. creative writing compared to academic research writing), has an influence on how students engage with a topic and how it might affect their learning. We anticipated that students would be more receptive to creative writing assignments as they don't carry the same amount of pressure to write in a voice/tone for an academic audience (academic language, traditional grammar rules, sentence structure, etc.). In turn, we hoped this would shift the focus from attention on the act of writing itself, to attention on the learning objectives. Questions 17, and 18 were included to analyze if student's responses to the assignment were influenced by their personal attributes of creativity and writing confidence.

Thematic Analysis of Creative Writing

Student "Arthropod or Not" creative writing submissions were analyzed using qualitative text analysis and manual coding (Kukartz 2014). The authors independently carried out an initial coding phase to reduce student writing into meaningful codes (Creswell 2012). Student submissions were selected randomly to review. The authors agreed to conduct open coding around the assignment regarding knowledge gained, fear, and misconceptions, evidence of entomological understanding as well as other 'ideas' they noticed in the students' writing. The initial coding of 15 student submissions was followed by discussion among the reviewing authors. The cycle of review and discussion continued for three more rounds until the group believed saturation was achieved with no new codes or patterns in student submissions being discovered. 30.1% of the total "Arthropod or Not" assignments submitted for ENTO 2003 were evaluated before saturation was reached. The authors stopped reviews after saturation (Fusch & Ness, 2015). From this process, the authors narrowed the thematic codes.

The reviewing authors also discussed their personal biases in coding the student writing and worked to attend to these. Personal biases included varying definitions of clichés and as well as what constituted as curiosity and the display of prior knowledge. When a potential bias was identified by an author, it was brought to the attention of the other reviewing authors to agree upon its coding. The authors

Table 1.

"Arthropod or Not" Questions

1. This activity changed how I perceived insects.	2. This activity made me perceive insects more positively.	3. This activity made me perceive insects more negatively.
4. I am more curious about insects after completing this assignment.	5. This activity helped me gain a better understanding and knowledge of insects.	6. I have a better appreciation for insects after completing this assignment.
7. I used internet sources to learn more about the insect(s) I was describing because of this assignment.	8. This activity was more engaging than a standard lecture.	9. This activity helped me learn better than if I had simply read an article/ paper about insects up-close.
10. I felt less anxiety about completing this assignment than I would have with a researched essay.	11. I feel like writing creatively is less pressure than writing academically.	12. I feel like I was able to better express my ideas through this assignment as opposed to a more traditional research essay or exam.
13. I prefer writing papers to taking exams.	14. I would like more writing exercises similar to this in the future.	15. The assignment instructions were clear and understandable.
16. I enjoyed this activity.	17. I enjoy being creative.	18. I enjoy writing.

then reconciled the codes into distinct thematic categories and determined the frequency of thematic codes observed in students' submissions as an indicator of prevalence.

Results

Student perspectives of activity

From a total of 295 students, 279 (94.5%) participated in the Likert Scale survey. Students expressed that the creative writing activity had a positive effect on their learning with 71.8% 'agreeing' or 'strongly agreeing' (reporting a 4 or above on the Likert Scale survey) to the statement that they enjoyed the assignment (Table 2, Question 16) (Figure 1, Question 16). Many students (74.0%) also reported 'agreeing' or 'strongly agreeing' that they learned more through this activity compared to other assignments, in part due to the interactive element (Table 2, Question 5) (Figure 1, Question 5). More importantly, the statement that most students disagreed with, was that Arthropod or Not made them perceive insects more negatively (Table 2, Question 3) (Figure 1, Question 3).

Some notable responses were:

"I defiantly [definitely] learned more with this assignment. It was interactive, and not just reading. I stared at and researched my insect before I began writing. I was hoping to get inspiration by staring at it, and it worked."

"I think this activity would help others understand and appreciate arthropods because it shows non-entomologist that bugs can be beautiful, not gross."

"I learned there is far more to insect's appearance than meets the eye. I find them a lot more pretty and appreciate their interesting appearance more than I had (before the assignment)."

"(This activity) made me think of arthropods as more beautiful and complex instead of just 'gross bugs'."

"I think this activity would help others understand and appreciate arthropods because it makes you explore arthropods past your preconceived notions and think more deeply into how they are structured."

Not only was the student feedback from the survey overwhelmingly positive, but the student's writing submissions also revealed themes that showed increased active learning, engagement of the students' sense of curiosity and wonder, and reduction of performance anxiety regarding writing in STEM. Several students reported being able to appreciate the beauty and complexity of arthropods rather than simply dismissing them as "gross". The initial feedback also established that close observation of insects has the potential to defamiliarize ideas about insects' appearance and promote "active" learning through encouraging independent research.

Regardless of whether a student self-identifies as a 'writer' or not, they still found this activity useful. Students also reported an increased sense of curiosity and reported using outside internet sources for further research, showing their willingness to participate in active learning (Figure 1, Question 7).

Student Creative Writing Analysis

As a result of coding analysis, the authors grouped student writing submissions into four emergent themes: the use of prior knowledge and facts (derived from class); misconceptions, assumptions, and clichés; finding beauty/ perspective shift; and curiosity (Table 3).

Table 2.

"Arthropod or Not" Likert-Scale Survey responses

Survey Question #	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
1	18.05	48.01	27.80	4.69	1.44
2	17.04	54.07	23.33	4.44	1.11
3	1.84	5.15	20.22	57.35	15.44
4	15.38	42.49	31.50	8.79	1.83
5	17.95	56.04	19.41	5.49	1.10
6	13.19	54.58	27.84	3.30	1.10
7	19.49	47.43	22.79	7.72	2.57
8	15.87	45.39	29.52	8.49	0.74
9	26.10	48.53	20.59	3.68	1.10
10	39.48	39.11	16.97	3.69	0.74
11	43.54	35.42	15.50	4.43	1.11
12	22.51	48.34	23.62	4.43	1.11
13	28.41	28.04	20.66	14.39	8.49
14	19.33	46.84	24.91	5.58	3.35
15	29.74	42.75	20.82	5.95	0.74
16	23.42	48.33	26.02	1.86	0.37
17	44.78	43.66	10.07	1.49	0.00
18	24.63	30.97	21.64	15.30	7.46

Note. (n=279) Likert Scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

Prior Knowledge

Prior knowledge learned both inside and outside of the ENTO 2003 lectures was commonly identified among the student submissions. Writing categorized under 'prior knowledge' included facts and terminology—such as using correct terms for arthropod anatomy (forewings, chelicerata [= spider fangs], bilateral symmetry, etc.)—correctly identifying the insect order by its scientific name and forming connections between arthropods and objects with uncommon knowledge and information. For example, a student submission which relied on prior knowledge read:

> The first object I chose can be found on slide 29. The Chelicerata's eyes look like reflective glass that translucent and symmetrical. The pair of chelicera or claw-like mouthparts taste like poison which gets injected into their prey. The spiders eight legs feel hairy and soft like a furry texture and is used for picking up scents, sounds, and vibrations. I can identify this spider as an arthropod as it is a chelicerate that possesses hard exoskeletons, segmented bodies, and jointed limbs.

The student's inclusion of facts and anatomy pointed to connections made from class content. Prior knowledge in student writing can be useful for instructors to evaluate whether students are retaining and correctly applying class information (Golick et al. 2021).

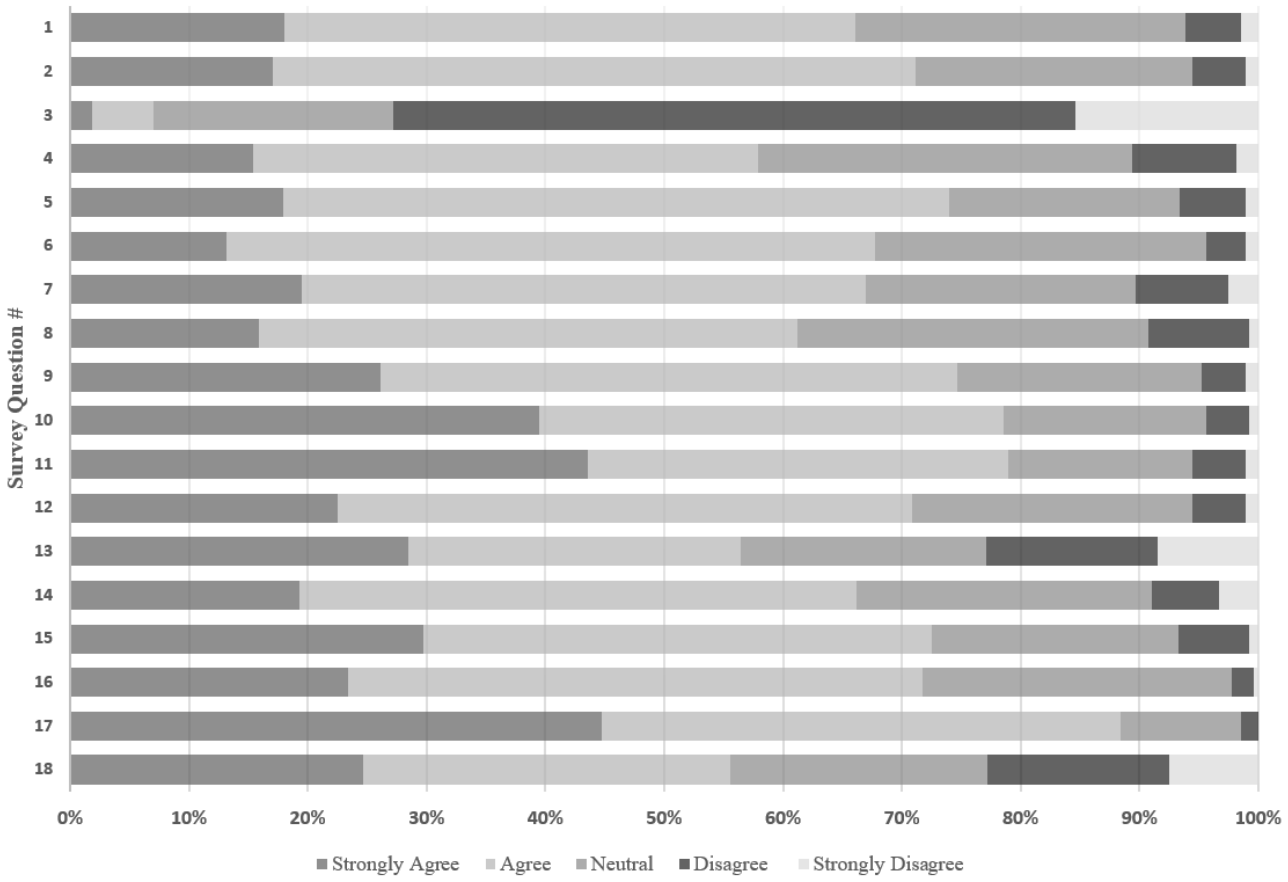
Misconceptions, Assumptions, and Clichés

Misconceptions and assumptions were another common element in student submissions. These were both categorized as false information—such as the inclusion of incorrect scientific facts—or incorrect speculation regarding information such as function, anatomy, danger, or sensory details. For example:

> The butterfly is an insect because it has wings. The butterfly has 4 legs. The butterfly also has scales, so it makes it a lepidoptera. Some of the traits of the butterfly feels scaly to the touch, tastes bitter because of the bright blue color it would leave a trouble taste in your mouth, smells like dirt and the outdoors, looks beautiful and colorful and finally sounds like fapping wings. The sunflower traits are soft, bitter and sour, smells sweet, looks perfect and pleasing to the eye.

Figure 1.

"Arthropod or Not" Likert Scale Responses



Note. (n=279)

Table 3.

Themes found in student's writing submissions by frequency

Theme	Total
The use of prior knowledge	56 (70.0%)
Misconceptions, assumptions, and clichés	56 (70.0%)
Finding "beauty" / shifts in perspective	66 (82.5%)
Curiosity	38 (47.5%)

Note. (n=80)

Among the misconceptions included in this submission are that all insects have wings and butterflies have only 4 legs. Further, the student speculated on the butterfly's sensory details based on their prior knowledge rather than using creative descriptions (bitter because of blue color, smells like dirt.) Despite the lack of accuracy, incorrect assumptions and misconceptions can still serve as an assessment of learning objectives. If students are incorrectly applying class information, instructors can identify what information requires further reiteration (Golick et al., 2021), which is useful for instructors to gain valuable insight on baseline class knowledge. Additionally, the addition of misconceptions and assumptions indicates a willingness to critically engage with the subject and form connections between prior knowledge and knowledge learned in class. Such connections support active learning (Larkin, 2015) and are important for overcoming entrenched misconceptions in the future (Golick et al. 2021).

Similar to misconceptions, clichés are defined as descriptions based on common assumptions. Clichés can include common sayings (ex. "quiet as a mouse"), or opinions (ex. "butterflies are beautiful"). For example, a student wrote:

> I think the arthropod in slide 11 is very pretty and has very bright colors. It has a shiny like look to it and looks like it could sparkle in the sun. The shape of it looks like it could make a heart of some sort and looks really cool. I think the arthropod has a very quiet sound or no sound at all, it seems like it would be quiet like someone sleeping. I think the arthropod is a butterfly.

Clichés arrive in the descriptions of the butterfly wings, appearing as if they would "sparkle in the sun" and seeming

to be quiet "like someone sleeping". It's obvious from these descriptions that the student has likely had limited interactions with butterflies—or a person who chronically snores in their sleep. Because clichés rely on collective knowledge and overused metaphors, their use is often attributed to a lack of personal connection, experience, and understanding of a topic (Zinsser, 2006; Carlson, 1995). Similarly, the descriptions used in the student example are clichés used to portray iridescence and silence—revealing a lack of engagement with critical thinking and personal experience through their false connections. Clichés can also indicate a limited experience with common expressions and/or printed text (Olson, 1982), and can suggest a novice level of creative writing skill (Zinsser, 2006; Stark 1999). Creative writers are taught early in their studies to avoid clichés as they undermine originality, detract from a writer's unique style and voice, and come across to the audience as 'unreflective' (Zijderveld, 1979). Their use by students can aid instructors in assessing student experience and level of creative writing competence.

Finding Beauty/Perspective Shifts

Another important theme was a shift of perspective in relation to insects. Most students reported finding unexpected "beauty" in the insect images. Some also described being surprised about how something they previously feared, such as spiders, were "cute" or less frightening up-close. For example:

> Exploring and evaluating the image of the arthropods and other objects was quite intriguing. Looking closely at an object then seeing the item in its typical presence emphasizes the importance of perspective. Some of the close-up pictures seemed startling or scary such as slide 18. However, once you see the creature in its typical being, the arthropod does not seem as scary. Despite the close-ups that revealed intimidating images, I found beauty in arthropods and objects, as well. For example, the colorful beetle can be appreciated even more by the colors displayed in the zoomed-in shot. The importance of perspective and judgment can change how objects and even insects are viewed.

As fear and disgust are often barriers to learning (Wagler & Wagler., 2021), assignments that increase appreciation, comfort, and familiarity are useful in helping students overcome existing biases. In turn, students may be more inclined to engage with the subject.

Curiosity

Many students indicated feeling curious or having further questions after completing this assignment. This indicates further engagement and can result in active learning. For example, a student's submission read:

> My experience looking at these objects was nice, it allowed me the opportunity to gain an even deeper look at certain arthropods and non-arthropods. Broadened my idea on what they look like and allowed me to gain knowledge on how similar they are to us as people. It made me excited to learn more about the make-up and their importance to the world. When looking at all the beautiful colors, it really makes myself go "wow" and appreciate what they are and how lucky we are to have them roaming the Earth. Some objects made me feel scary, but with time and better understanding it begins to get pushed away. Appreciation occurs.

The student indicated that while they were scared initially, they were excited to learn about insects' make-up and importance.

Discussion

Subjects such as entomology, agriculture, mycology, herpetology, chemistry, and cell-biology are especially at risk for a lack of non-major student engagement due to their surrounding biases and misconceptions (Wagler & Wagler, 2021). Instructors must creatively engage with students' senses of wonder, curiosity, critical thinking, and observation—all of which are vital to scientific learning. In his essay 'Curiosity, Wonder, and Education Seen as Perspective Development', Opdal (2001) wrote that "an important gateway to new discoveries, the experience of wonder may lie at the bottom of, even be a prerequisite for, the development of creative and critical persons." By stimulating student's curiosity and wonder about the natural world, it motivates them in turn to perform frame-directed research and critically analyze the world itself (Opdal, 2001), thusly making wonder and curiosity essential components of skills in critical thinking and observation. Without such engagement, students risk lacking a connection to the object of study—leading to diminished interest and motivation to learning (Hadzigeorgiou, 2005).

Novelty of experience is another crucial aspect in the engagement of curiosity and wonder. The multimodal nature of the "Arthropod or Not" assignment allowed students the opportunity to experience insects in a novel way—a way in which they might not have experienced otherwise. Recent research has shown that multimodal assignments serve as a gateway to learning for diverse student populations, especially those who are ESL speakers or neurodiverse (Yvonne et al., 2017; Álvarez, 2016). This is especially relevant to a general education course which serves a large population of students—most of whom are non-majors. Additionally, multimodality has a strong connection with rhetorical knowledge, allowing students a greater focus on the underlying purpose of the lesson (Bearden, 2016). The connection of multimodality to rhetorical knowledge is further supported by Krom & Williams (2012) who used story-telling activities during instruction of accounting students, resulting in increased student engagement and learning outcomes.

By combining the benefits of multimodality, creative writing, and science—we discovered that the "Arthropod or Not" assignment increased student knowledge, heightened curiosity of the natural world, and positively influenced student perception of insects (Figure 1; Table 3). Further, the student's writing included common themes of prior knowledge and misconceptions which could be used by instructors to identify gaps in knowledge and establish a baseline understanding of the topic (Table 2). We also

discovered that misconceptions are often connected with clichés, highlighting the importance of personal experiences. Because close interactions between insects and non-major students are relatively rare, some students relied on common, overused descriptions to inform their writing. It is currently unclear whether misconceptions inform clichés, or if clichés inform misconceptions. Future research should be conducted on this subject.

In addition to the academic benefits of this assignment, it is also important to note its possible effects on student identity and confidence. The lowest self-reported score on the Likert Scale was "This activity made me perceive insects more negatively," and positive responses to questions 5-12 (Table 1) indicate engagement with the assignment. This further indicates that whether students think of themselves as "writers", or being gifted at writing, they were still able to enjoy and learn from this assignment.

Our current academic climate emphasizes the divide between creative studies and STEM fields. Such false dichotomies can result in feelings of alienation from certain subjects. This assignment dispels the false notion of academic divides and encourages student confidence across all areas of study, supporting STEAM learning, and multimodality. Moreover, creative writing may serve as a gateway for student confidence in writing, especially in STEM classrooms. Further research should be conducted on how creative writing assignments assigned earlier in a course influence later outcomes and confidence in academic writing.

Incorporating creative writing into STEM classes may be important for overcoming reluctance to learning caused by fear, bias, self-identity, and lack of accessibility. Since instructors of all subjects can easily access up-close images from the internet, this assignment can be extended to nearly any agricultural science. Furthermore, as this activity helps students to evidence their nature connectiveness through their writing, and thus can be used as a formative or summative assessment for instructors or as a reflective exercise for learners in their thinking about the intersections between agriculture, natural areas, and human society.

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