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Impact of the Arts on Public Perception, Comprehension, and Retention of Scientific Research

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Cover Page Footnote
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Abstract
Communicating research to broad audiences is a fundamental task for scientists. Art is hypothesized to be an effective medium for improving public perception of research, as well as student comprehension and retention of scientific discoveries. To test these hypotheses, we first created an interactive art exhibit with 20 original pieces aimed at communicating findings from two recently published papers. Next, to test whether art improves public perception of research, we asked visitors of the art show to fill out surveys about their perception of research before and after visiting the exhibit. Next, using content quizzes, we tested whether interacting with art allowed ecology students to better retain and comprehend scientific findings compared to reading scientific abstracts. Participation in the art exhibit caused a 20% improvement in perception of research for individuals with non-scientific backgrounds. However, participation in the art exhibit was less effective for participants with scientific backgrounds (10% improvement). Next, contrary to our hypothesis, participation in the art exhibit did not improve ecology student comprehension and retention of scientific material. In contrast, students scored the highest when reading abstracts. Collectively, this suggests that the use of art can facilitate scientific appreciation but is most influential with individuals with non-scientific backgrounds.

Study Goals

Clearly communicating research to broad and diverse audiences is fundamental to the role of scientists. To this end, many have hypothesized that art has the potential to be an effective and powerful medium for communicating major research findings to the general public (Curtis et al., 2012). Curtis et al. (2012), for example, displayed pieces of art and conducted performances at a national ecological conference attended by professional ecologists, and then administered a survey to the ecologists that viewed the art and attended the performances. The researchers found that over half of the respondents believed that art

could positively influence the perception, comprehension, and retention of scientific information.

To further explore the hypothesis that art can positively influence science communication and to build upon previous work, this research aims to understand whether art can facilitate science communication in audiences beyond professional ecologists. Specifically, we are interested in understanding how art might influence the perception of research in members of the general public who have different academic backgrounds. In addition, to understanding how art alters the perception of research, this study also investigated whether art can be used to improve college student comprehension and retention of ecological findings. Towards this goal we asked two questions:

1. How does art alter the general perception of ecological research in the people with different academic backgrounds?
2. Does art improve comprehension and retention of scientific findings relative to traditional abstracts?

Methods

Creating the Art Exhibit

To address these questions, we first created an exhibit with 20 pieces of original art designed to engage visitors through interactive visual, hands-on, and digital elements. This exhibit was designed to communicate the major findings of two recently published papers (Hua et al., 2015, and Hua et al., 2016). Specifically, the art show communicated the findings of Hua et al. (2015) that wood frog tadpoles exposed to non-toxic levels of the pesticide, carbaryl, as embryos were capable of rapidly inducing increased tolerance to

lethal concentrations of carbaryl via the process of phenotypic plasticity. To portray the discoveries described in Hua et al. (2016), the art work highlighted the finding that the parasite (*Echinoparyphium* Lineage 3) are highly sensitive to the carbaryl pesticide during their free-swimming life cycle stage (Hua et al. 2016). The artwork involved in the exhibition included various multi-media installations from digital media to sculptural and live specimens. The art show was presented in a conference room within Binghamton University's Glenn G. Bartle Library.

We created and displayed three acrylic paintings and one digitally generated painting. The three acrylic paintings provided a close-up view of the trematode parasite (Figure 1), depicted wood frog tadpoles swimming in their natural environment (Figure 2), and portrayed the effects of carbaryl and trematode infection on a wood frog tadpole (Figure 2). The digitally generated image was produced via Adobe Illustrator CC 2015 and portrayed an idealized wood frog tadpole via a cubist lens (Figure 3). All four paintings were either painted or printed on canvas and displayed on the wall.

Figure 1. Close up image of trematode parasite (*Echinoparyphium*)

Figure 2. Clockwise from the top-left: acrylic painting depicting wood frog tadpoles in their natural environment; acrylic painting portraying the effects of carbaryl and trematode

infection on a wood frog tadpole; and sculpture of the chemical structure of carbaryl in three-dimensional space.

Figure 3. Painting of an idealized wood frog tadpole via a cubist lens

The art exhibit also contained eight sculptures depicting the chemical structure of carbyl in three-dimensional space (Figure 2), the life cycle of a wood frog tadpole (Figure 4), a free-swimming trematode (Figure 5), and four tadpoles depicting phenotypic plasticity (Figure 6). All sculptures were created using aluminum foil, liquid glue, coffee filters, primer, and acrylic paint. To create the shape of the structure, we molded multiple layers of aluminum foil together. Next, we applied four to six layers of coffee filters to the aluminum skeletons of these sculptures using liquid Elmer's glue to create a paper maché mold. Once the glue dried, to smoothen the surface of each sculpture and to create an appropriate medium for acrylic paint to adhere, we applied gesso to all surfaces of each

sculpture. All sculptures were hung on the walls, except for the carbaryl molecule and trematode models, which sat on tables.

Figure 4. Sculptures depicting the life cycle of a wood frog tadpole.

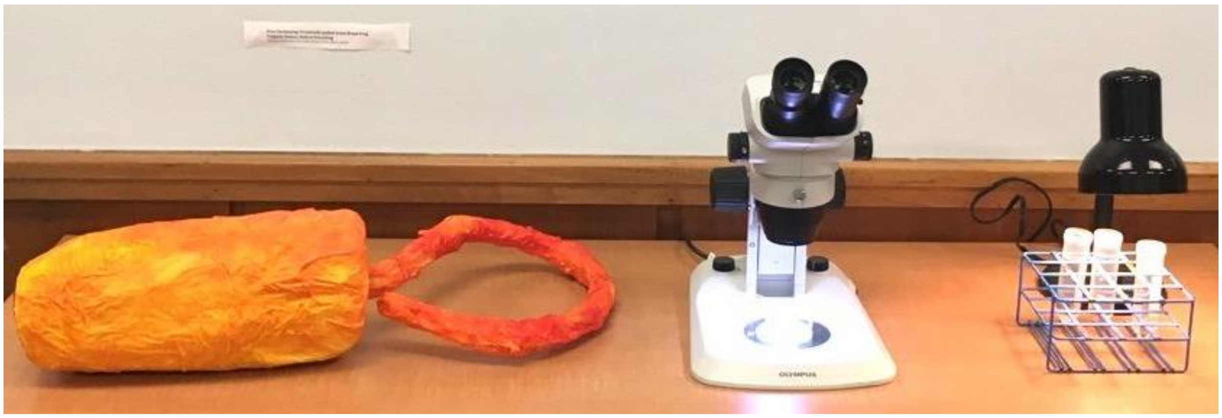

Figure 5. From left: Sculpture of a free-swimming trematode (*Echinoparyphium*); and a dissecting microscope to observe live free-swimming trematodes and freshwater snails.

Figure 6. Four sculptures of tadpoles exhibiting phenotypic plasticity, alongside two infographic posters conveying research findings and laptops displaying an interactive walkthrough of research methodology.

We also created two infographic posters (Figure 6) designed to convey the major research findings from both papers in a bold and concise fashion. Both were created using Adobe Illustrator CC 2015 and were displayed on the wall.

In addition to physical art pieces, laptops were set up along the perimeter of the room displaying an interactive walkthrough of the methodology behind the two scientific papers (Figure 6). This exhibition piece was made using the website-creator software, wix.com, and included custom-made visuals and animations to convey the experimental processes of both papers. The visuals included in the website were created using Adobe Illustrator CC 2015 and Adobe Photoshop CC 2015.

Video footage of trematodes (Figure 7) swimming in a controlled lab setting was spliced together and projected on the far wall of the conference room. We made these videos in the Hua Lab by illuminating a beaker full of free-swimming trematodes collected from snails *(Helisoma trivolvis).* Using cardboard stock paper, we also depicted the complex life cycle of the trematode parasite (Figure 8).

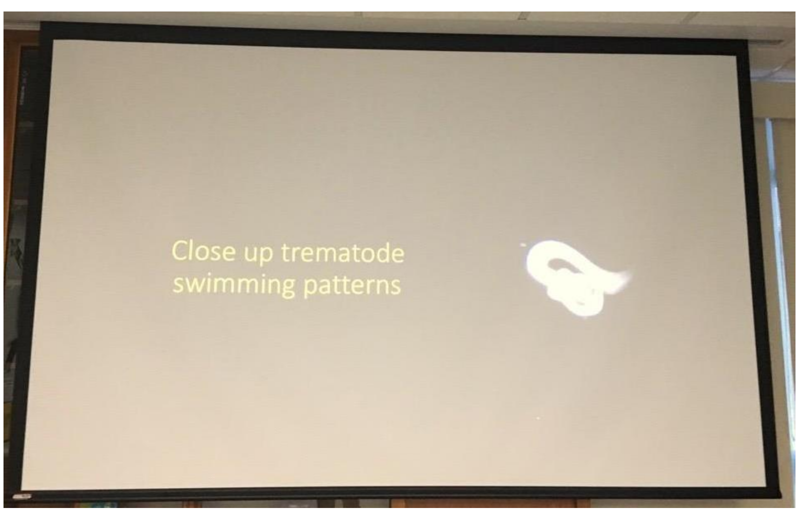

Figure 7. Projected video footage of trematodes swimming in a controlled lab setting.

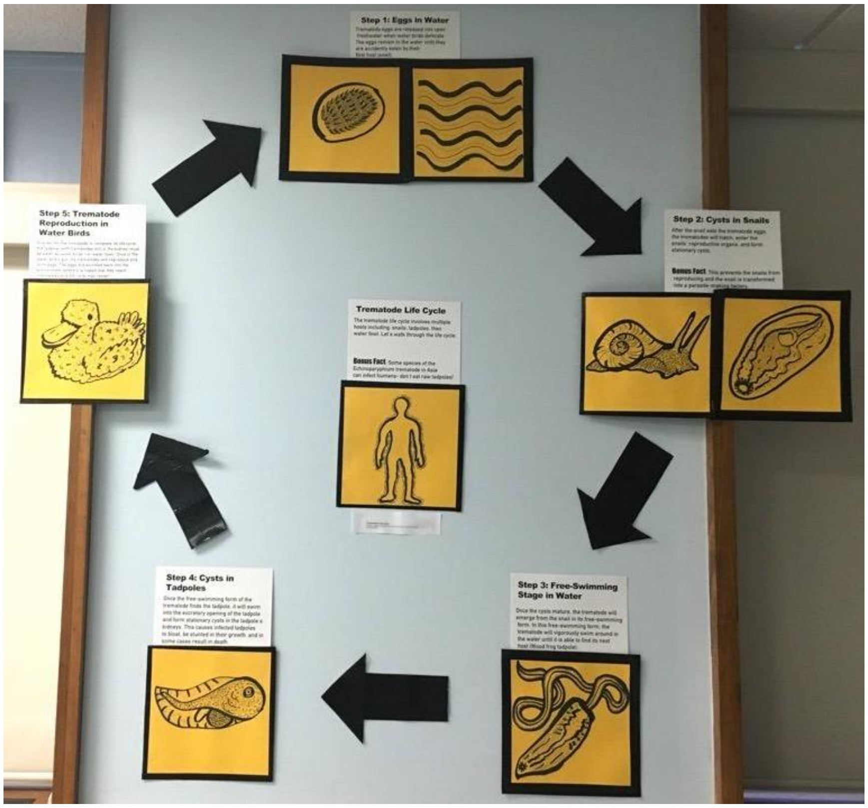

Figure 8. Images depicting the life cycle of the trematode parasite.

We also created an interactive station where visitors of the art show could use a dissecting microscope to observe live free-swimming trematodes (Figure 5). This station included living snails, a lamp to keep the trematodes active, a dissecting microscope, microscope slides, and pipettes to transfer trematode samples to and from the microscope.

Finally, we set up with an exhibit representing an optimal freshwater environment for wood frog tadpoles (Figure 9). To create this exhibit, we filled an aquarium tank with 25 L of well water. We added natural aquatic vegetation and 15 live wood frog tadpoles. The use of tadpoles in this display was approved by Binghamton University’s Institutional Animal Care and Use Committee (Protocol 757-16).

Figure 9. Aquarium with natural aquatic vegetation and 15 live wood frog tadpoles.

Testing the general public on if the art installation altered their opinion of research

To investigate whether participation in an interactive art show influenced the public perception of scientific research, we opened our interactive exhibition to the general public and Binghamton University populace on 2 May 2016. We asked visitors of the art show to fill out an anonymous survey detailing their scientific background and interest in scientific research prior to and after viewing the exhibit (Appendix 1). The anonymous survey collected information regarding highest degree of education, profession, gender, academic background/ major, as well as asked participants to rank their interests in scientific research on a numbered scale before and after viewing the show. Lower ranks indicate lower interest in research and higher ranks indicated higher interest in research.

Testing comprehension and retention

Using 65 college student volunteers, we tested the hypothesis that the art show would improve the ability for college students to comprehend and retain scientific findings. To control for background ecological understanding, we limited the volunteers to students enrolled in the Spring 2016 BIOL 355 Ecology class. On 2 May, volunteers were randomly divided into three treatment groups (art show, abstract, control). Students in group 1 (n= 22) visited the art exhibit, students in group 2 (n= 21) read the paper abstracts, and students

in group 3 (n = 22) acted as the control and visited neither the art show nor read an abstract. The text in the abstract was identical to the text presented in the art show (Appendix 2).

Prior to the start of the experiment, all students were given a brief survey to measure their baseline level of interest in research. Following the survey, students in group 1 visited the art show and students in group 2 read the abstract. Students in group 3 were immediately given a brief, anonymous multiple-choice quiz to measure their baseline comprehension of the research select papers (Appendix 3). To account for variation in learning speed, we did not restrict the time students spent exploring the art show, reading the abstract, or doing both. We instructed all volunteers to use as much time as they needed to adequately digest the information. After learning about the research, Groups 1 and 2 were given a brief, anonymous multiple-choice quiz to measure their comprehension of the select papers (Appendix 3). Students also answered the survey measuring their level of interest in research after participating in their learning treatments (Appendix 1).

One week later, on 9 May, all of the student volunteers completed the same multiple quiz to gauge their retention of that information they learned by completing their learning treatments. We also collected information regarding the major(s), year in college, overall GPA, ethnicity, research experience, and scientific background of all volunteers. All students were kept blind to the purpose of the experiment until after the completed the final quiz on 9 May. All methods used in this study were approved by Binghamton University's Human Subjects Research Review Committee (Protocol Number: 3780-16).

Statistical analysis

Using regression analyses, we found no relationship between gender, profession, or ethnicity and quiz scores in either our comprehension or retention tests. Therefore, we did not include these variables in our model.

Experiment 1, Perception of research: To understand whether participation in the art exhibit changed public perception of ecological and evolutionary research, we first conducted a repeated measures ANOVA, analyzing participant ranking of research before and after interacting with the art exhibit. Next, to better understand how differences in academic background influenced perception of science before and after participating in the art exhibit, we calculated the percent change in research perception for participants with non-science vs. science backgrounds vs. students taking BIOL 355 (Ecology) and conducted a univariate ANOVA.

Experiment 2, Comprehension and retention: To understand whether art can influence student comprehension and retention of research, we calculated quiz scores (percent of questions answered correctly). Next, we conducted a rANOVA to determine whether treatment (abstract vs. art exhibit) influenced participant quiz scores immediately following participation in the study and after 1 week. To Account for potential differences in participation baseline knowledge, we also conducted comparisons between the two treatment groups and the control treatment

Results

Participant background

A total of 81 patrons were recorded as participating in the survey, but we dropped 11 surveys due to missing information. Of the completed surveys, the majority of participants were affiliated with Binghamton University (97%): 85% identified as students, 13% identified as non-students, and 2% did not report their profession. Of the participants, 54% had non-science backgrounds and 46% had science backgrounds. Science backgrounds included the following majors or professions: biology (25%), computer science (21.9%), environmental science (9.4%), nursing (9.4%), neuroscience (6.3%), psychology (18.8%), physics (6.3%), and physicians (3.1%). We considered the following majors or professions as non-science backgrounds: accounting (5.3%), education (2.6%), economics (10.5%), English/creative writing (18.4%), German (2.6%), graphic design (2.6%), history (5.3%), human development and sociology (7.9%), public administration and management (5.3%), math (7.9%), music (2.6%), philosophy (2.6%), political science (15.8%), Spanish (5.3%), and theater (5.3%).

Public opinion on research

The rANOVA found a significant main effect of time (Wilk's $\lambda = 0.55; p < 0.001$) with a significant positive increase in perception of research for participants after visiting the art exhibit ($p = 0.001$; Figure 10). The ANOVA found a significant main effect of academic background on the change in perception of research ($F_{1, 68} = 5.5$; $p = 0.02$), with the change in perception of research for participants with non-science backgrounds being significantly larger than the change in perception of research for participants with non-science backgrounds.

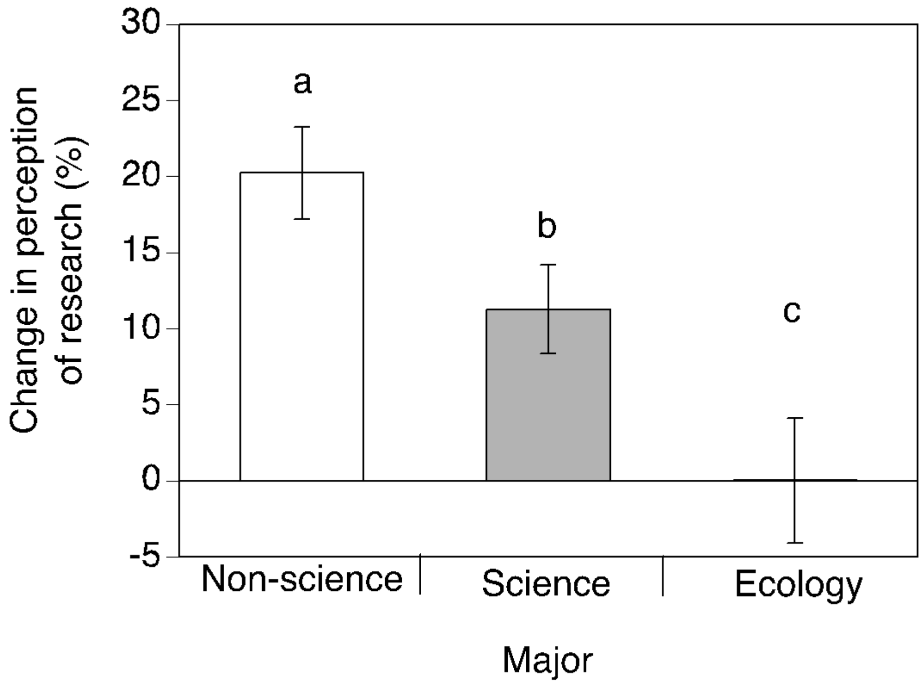

Figure 10. Average change in perception of research for participants with backgrounds after visiting the art exhibit. The three subject groups identified in the graphic are those with non-scientific backgrounds, those with scientific backgrounds, and those specifically studying ecology.

Testing comprehension and retention

The rANOVA found a marginally non-significant change in participant quiz scores across time (Wilk's $\lambda = 9.5$; $p = 0.08$). The analysis also indicated that there was no significant interaction between individuals and their quiz scores across time (Wilk's $\lambda = 9.9$; $p = 0.47$; Figure 11). However, we did find a significant interaction between treatment and time (Wilk's $\lambda = 7.8$; $p = 0.001$). For the first quiz measuring comprehension, students in the abstract treatment scored significantly higher than students in both the art and control treatments ($p = 0.001$; $p < 0.001$, respectively) and students in the students in the art treatment scored significantly higher than students in the control treatment ($p < 0.001$). For the second quiz measuring retention, students in the abstract treatment scored

significantly higher than students in the control treatments but not the art treatment ($p = 0.03$; $p < 0.49$, respectively). Students in the art treatment did not score significantly different than students in the control treatment ($p = 0.5$).

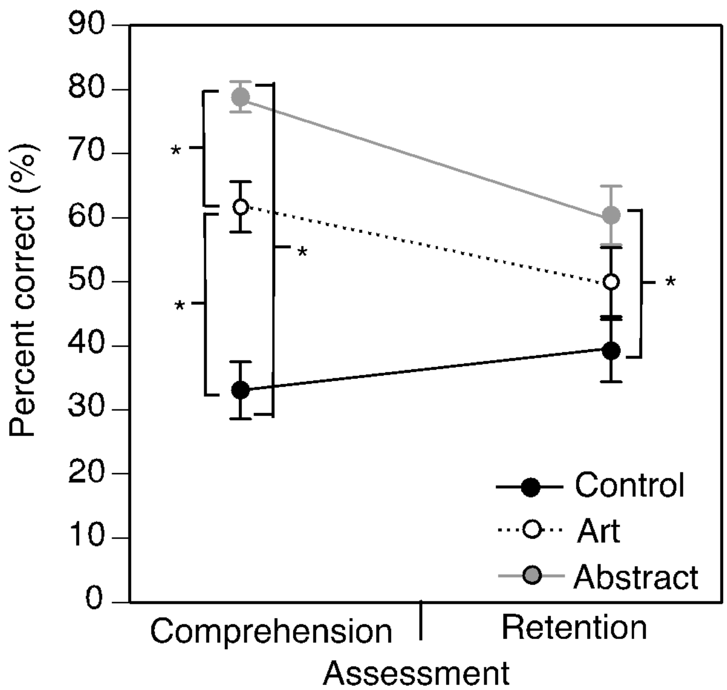

Figure 11. The comprehension and retention of scientific information in ecology students from three treatment groups—art show, abstract, and control.

Discussion

These findings suggest that art can be an effective tool for generating public interest in scientific research. However, art was most effective in changing public perception of research for participants with non-science backgrounds. Next, participation in the art exhibit did not improve the comprehension and retention of scientific material of ecology students. Instead, students scored the highest when reading abstracts. This suggests that for students that may be more accustomed with comprehending and retaining scientific

information via abstracts, the use of art may be inhibitory. In sum, art can facilitate scientific appreciation but it is most influential with individuals with non-scientific backgrounds.

Public perception study

Generally, we found that participation in the art show led to an increase in the positive perception of research. However, the magnitude of change depended on the scientific background on the participants. Participants without science backgrounds experienced the largest increase in positive perception of research (20.2 ± 3%), followed by those with general science backgrounds (11.3 ± 2.9%), and finally those with a specific background in ecology (0.01 ± 3.9%). The variation in the change in perception of research may be due to differences in how participants viewed research prior to the experiment. Students with ecological background started with the most positive perception of research (10.54 ± 0.78%), followed by students with science backgrounds (9.2 ± 0.61%), then students with non-science backgrounds (8.65± 0.49%). Collectively, our results suggest that art can help to demystify the scientific process and generate positive interest in research. This effort is most effective for individuals with non-science backgrounds.

Comprehension study

We found that ecology students who participated in the art show and read the abstract did 58% and 46% better, respectively, on the content quiz compared to those in the control. However, contrary to our predictions, students that participated in the art show did not comprehend scientific material better than compared students who read the abstract. Instead, students in the abstract group performed 21.8% better than students who participated in the art show. Therefore, for ecology students, paper abstracts were more

beneficial for short-term comprehension of scientific findings than participation in an art exhibit. This suggests that traditional methods of conveying scientific information using paper abstracts may be more effective for students with experienced scientific backgrounds. A previous study has shown that scientifically oriented students tend to rely more on textual formats than hands-on approaches in comparison with artistically inclined students (Kolb A., and D. Kolb. 2005). The ecology students, since they were studying a scientific field, may have had learning styles that were better oriented to the textual information conveyed in the paper abstracts rather than the hands-on experience of the art show. It is also possible that the extra information portrayed in the art exhibition distracted students from the main findings of the papers. While the text provided in the art show was identical to that of the abstract, the additional art may have acted as a distraction hindering student ability to identify important concepts to learn, as cluttered vision has been shown to hinder focus on a particular subject (Mcmains, S., and S. Kastner. 2011). That is not to state that the art exhibition was cluttered, but to suggest that focus on important concepts may have been inhibited due to the variability and close proximity of artwork displayed during the experiment. Future studies may consider other ways of presenting the art as to more effectively highlight important information and lessen distraction of the subjects.

Retention study

Data collected for retention rates show a level, roughly average retention rate of approximately 50-percent correct scoring across all groups; however, the art group's score, though initially lower than the abstract group's, fell by less over the course of the study. Specifically, the art group scored 50-percent correct; the abstract group scored 60-percent correct; and the control group scored 40-percent correct on average. The outliers for all

three groups suggest that the average overall retention rate across all three groups was roughly 50-percent. It may be suggested that there is a maximum retention rate of information by students, regardless of how that information was presented to them, based on this data. While that may be argued, it is significant that there was less information lost to the art group than there was to the abstract group in terms of percentage of questions answered correctly. This may stem from students answering the same question incorrectly on both quizzes. Some people may have found certain aspects of the research more interested, and thus their memories latched onto those pieces of information more firmly than other specific parts; those parts that were not as interesting were glossed over and forgotten when it came to be tested upon. This may also be caused by the visual elements of the art exhibition being overall more memorable and more universally comprehensible than the paper abstracts, thus ensuring that certain key concepts. Further testing should be done to corroborate these findings, as a single study does not show a trend nor substantiated data. Testing for retention one day after the initial comprehension test as opposed to waiting a week may also yield different results, which may be something to consider for future research. Involving art students in the testing process as volunteers in contrast to ecology students could also provide a wider scope of how art influences people differently in comprehending, retaining, and appreciating scientific research.

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Appendix 1

PLEASE **DO NOT** WRITE YOUR NAME- This is an **ANONYMOUS SURVEY**

Occupation: ______________________________.
Highest level of education:___________. **Major (if applicable):___________.**
Gender identity: M F Non-Binary Prefer not to disclose
Ethnicity:_______________. Prefer not to disclose

BEFORE PARTICIPATING IN THE ACTIVITY

1. Please circle a number that best represents your interest in the pursuing research as a career?

1	2	3	4	5
Not interested		Indifferent		Interested

2. How likely would you spend 15 min/ day of your free time learning about pesticides in the environment (includes: browsing websites, reading news article, talking to professors, journal articles)?

1	2	3	4	5
Not likely				Likely

3. How likely are you to spend 15 min/ day of **your free time** learning about disease ecology (this includes browsing websites, reading news article, talking to professors, or journal articles)?

1	2	3	4	5
Not likely				Likely

AFTER PARTICIPATING IN THE ACTIVITY

1. Please circle a number that best represents your interest in the pursuing research as a career?

1	2	3	4	5
Not interested		Indifferent		Interested

2. How likely would you spend 15 min/ day of your free time learning about pesticides in the environment (includes: browsing websites, reading news article, talking to professors, journal articles)?

1	2	3	4	5
Not likely				Likely

1. How likely are you to spend 15 min/ day of **your free time** learning about disease ecology (this includes browsing websites, reading news article, talking to professors, or journal articles)?

1	2	3	4	5
Not likely				Likely

Appendix 2

Study #1 Wood Frog Tadpoles and Carbaryl

The role of plasticity (ability for individuals with the same genes to express different traits in different environments) in shaping adaptations is important to understanding the expression of traits. With increasing human impacts on the environment, one challenge is to consider how plasticity shapes responses to anthropogenic stressors such as contaminants. Using populations of wood frogs (Lithobates sylvaticus) located close to and far from agricultural fields, we discovered that exposing some populations of embryos and hatchlings to sublethal concentrations of the insecticide carbaryl induced higher tolerance to a subsequent lethal concentration later in life. Interestingly, the inducible populations were located far from agricultural areas. In contrast, the noninducible populations were located close to agricultural areas. This is the first study to demonstrate inducible tolerance in a vertebrate species and suggest a novel way for amphibians to rapidly achieve pesticide tolerance.

Study #2: Tadpoles, Carbaryl, and Trematodes

Wild populations increasingly encounter synthetic chemicals, such as pesticides. Exposure to pesticides may influence ecological interactions (i.e. host-parasite). The effect of pesticides on host-parasite interactions can depend on environmental context. To date, our understanding of parasite phenotype in shaping disease outcome is limited. We investigated how pre-exposure of hosts to pesticides and environmental context (pesticide absent vs. present) shaped trematode host preference. Using trematodes in the free-living stage, we found that trematodes encysted preferentially in hosts not pre-exposed to the pesticide in pesticide-free arenas but encysted more in pre-exposed hosts in pesticide arenas. Thus, early exposure to pesticides and environmental context was important to understanding parasite host choice. Collectively, this work illustrates the importance of considering environmental context to understand disease dynamics.

Appendix 3

PLEASE **DO NOT** WRITE YOUR NAME- This is an **ANONYMOUS SURVEY**!

Major: ________________________________. **Overall GPA:__________.**
Year (FY, SO, JR, SR):___________. **Expected letter grade in Biol 355: .**
Gender identity: M F Non-Binary Prefer not to disclose
Ethnicity:_______________. **Research experience?** Y or N

Multiple Choice Quiz- Please select the correct answer

1. What trematode life stage did we focus on in the trematode study (Study #2)?
    a. Egg stage
    b. Free-swimming stage
    c. Cyst stage (in snail)

2. In Study #1 (Tadpole and Pesticide), what was the mechanism that allowed tadpoles to induce tolerance to pesticides?
    a. Natural selection
    b. Phenotypic plasticity
    c. Constitutive tolerance

3. Based on Study #1 (tadpole and pesticide), which tadpole is most likely to be able to induce tolerance to pesticides
    a. Tadpoles that lived farther from agriculture
    b. Tadpoles that lived closer to agriculture
    c. All tadpole populations showed equal levels of induced resistance

4. Based on the trematode study (#2), if you were a trematode and there is pesticide in the water/arena that you are swimming in, which tadpole would you choose to infect?
    a. The tadpole that has never been exposed to pesticides
    b. The tadpole that was previously exposed to pesticides
    c. It doesn't matter- trematodes can't detect pesticides

5. Where do trematodes form stationary cysts in the snail?
    a. Kidneys
    b. Reproductive tissue
    c. Liver