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ORIGINAL ARTICLE

"Fin-tastic Fish Science": Using a comic book to disseminate and enhance science literacy

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Abstract

The need for more interaction between scientists and the public is widely recognized. If we want the public to support science, we need to effectively convey its nature and benefits. Science outreach can help reverse negative attitudes, spark curiosity and enthusiasm, and encourage communities to support science. Better communication tools than traditional texts are needed to increase positive attitudes toward science, which may lead to more self-motivated engagement with science in the future. The unique language of comics has the potential to portray abstract scientific concepts more easily than just words. Here we report findings from an assessment of how a science comic can affect student learning and attitudes toward engaging with science, compared to more traditional written texts, a journal article, and popular science summary. We used a pre- and post-reading questionnaire to measure learning gains and attitudes toward science engagement. Students who read the comic have the highest learning gain, equivalent to a journal publication, and see the most positive changes in attitude toward engagement with science. Our findings suggest that science comics could be a highly effective form of communication and outreach among the public.

1 | INTRODUCTION

Public science literacy in the United States is poor (OECD, 2019; TIMSS, 2019). According to the National Assessment of Education Progress, between 2015 and 2019, the science proficiency of fourth graders significantly decreased and has remained low among eighth and 12th graders (NCES, 2022). Many Americans continue to lack a basic understanding of scientific concepts and therefore do not value how scientific knowledge can be used to draw evidence-based conclusions. Improving science literacy among the public is difficult because science content delivered by publication in traditional scientific journals is both intimidating and inaccessible (Hayes, 1992; Plavén-Sigray et al., 2017).

As scientists, we aim to remove this barrier by improving our ability to communicate science to a wider audience. Most researchers focus on just a few traditional outputs such as journal articles, books, and conference presentations, which are inaccessible to the public (Alperin et al., 2019). Communication with the public most often occurs through collaboration with journalists, which results in newspaper, radio, television, and magazine stories (Friedman, 2008). One of the most popular forms of accessible text created for the public through journalists is that of a research summary document. These are usually one- to two-page documents which clearly summarize key findings and takeaways from a research project (Ross-Hellauer et al., 2020). Another method of communication is through talks or workshops held by scientists themselves, which can be complemented by communication tools such as PowerPoint presentations, videos, or hands-on activities (Stevens, 2011). However, these methods of communication are still challenging, as it is often difficult to simplify specialized scientific language and concepts in a manner the public can understand and engage with (Friedman, 2008; Shonkoff, 2000). Additionally, the public often lacks background information that is needed to understand the science being communicated (Brownell et al., 2013; Goldstein et al., 2020; Hunter, 2016).

We have two communicative study objectives. First, we aim to effectively convey the nature of science and its benefits. Second, we aim to reverse negative attitudes toward engaging with science, thus encouraging public engagement. Given that visual art has documented the natural world for thousands of years, and scientific illustration is an effective method for explaining scientific concepts, in this paper we report on our efforts that capitalize on the intersection of art and science to develop a comic book to communicate complex scientific material in an engaging and easily comprehensible way with the goal of increasing positive perceptions toward science (Ford, 1993). This comic was developed for people who are currently in high school and high school graduates, who may or may not complete college.

Comics are sequential art where the shape, size, and relationship between panels convey as much information as the pictures and text itself. Comics are also uniquely designed to break down information into smaller, more digestible units (panels), which can be reassembled into a larger picture, often creating visual narrative sequences that would be impossible to translate into words alone (McCloud, 1994, 2008). Scientific papers and texts can be challenging to read and understand, (Elhai, 2003; Tang & Rappa, 2020). The unique language of comics that allows for the visualization of abstract scientific concepts may be a useful tool for improving engagement and learning among the public. While this study focuses on using the visual language of comic books for science communication, it should be noted that when engaging with a wide audience, comics may also be challenging, thus, it is important to incorporate different learning styles and to convey science through multiple channels (e.g., text, audio, and visual).

Tatalović (2009) has reviewed the literature surrounding science comic books and their role in science education. While many articles propose that comics can be a useful learning tool, studies on their educational effectiveness are scarce (Tatalović, 2009). There are a few studies providing evidence that comics can be useful in teaching children about science. However, they suffer from small sample sizes and lack controls for the novelty factor of comics in the classroom (Kruger & Shariff, 2001; Rota & Izquierdo, 2003). In higher education, a comic book about evolution and neurobiology, *Optical Allusions*, was shown to be as effective as a traditional textbook when teaching material to college students, but significantly better when it came to engaging nonmajors (Hosler & Boomer, 2011). Similar results were seen in a study by Spiegel et al. (2013), which tested the efficacy of using comics to engage high school students with the topic of virology. Students who read science comics were five times more likely to continue reading material about viruses than students who were given an equivalent text essay. Similar to the nonmajors who read *Optical Allusions*, the effects were also more pronounced among students who began the study with the least favorable views toward science.

Core Ideas

- It is difficult for researchers to simplify specialized scientific language and concepts for the public.
- Comics can visually portray abstract scientific topics, making them useful for education and literacy outreach.
- We created a science comic, *Fin-tastic Fish Science*, to measure understanding and science engagement attitudes.
- Students who read the science comic had a learning gain equal to students who read a traditional journal article.
- Comic readers reported their enjoyment toward engaging with science increased and their intimidation decreased.

These limited studies suggest that comics have the potential to be used as a learning medium in the classroom, but there are even fewer empirical studies on the effectiveness of comics as a dissemination tool for science outreach among the public (Farinella, 2018). A Portuguese government initiative with the goal of improving public perception of stem cell research collected voluntary feedback from members of the public exposed to different communication treatments such as science summary articles, posters, radio interviews, illustrated texts, and comics. Interestingly, comics were rated as the most effective medium for understanding the content by 46% of the participants, followed by illustrated texts at 21.5% (Varela Amaral et al., 2015). Another study investigated the effects of a comic book on learning and attitudes toward nanotechnology among members of the Taiwanese public. Comics were found to be just as effective as traditional texts at improving understanding and attitudes toward engaging with science (Lin et al., 2014).

In this study, we asked whether college students would learn more from, and perceive engaging with science in a more positive light after reading a scientific comic book, compared to more traditional written texts. We tested whether a comic book, capable of visually portraying abstract concepts in science, was more engaging to students than journal articles or popular science summaries. We used a pre- and post-reading questionnaire to determine if the retention and perception of scientific content among non-biology major undergraduate students differed by dissemination approach. We hypothesized that after reading a scientific comic book, students would (1) have higher learning gains when tested on content compared to others who read more traditional text-based scientific writing and (2) have a positive change in perception toward engaging with science compared to others who read more traditional text-based scientific writing. Our goal was to provide valuable pedagogical data toward improving both science communication and literacy that can be adopted by others across diverse topics.

2 | MATERIALS AND METHODS

2.1 | The comic book

Fin-tastic Fish Science is a comic book written and illustrated by Rose Wayne that uses a published paper from the Maruska Lab about the neuroscience of social defeat in an African cichlid fish *Astatotilapia burtoni* (Butler et al., 2018) as a framework for the story (Wayne, 2022). The comic book was designed to be accessible to the general public. The story of *Fin-tastic Fish Science* centers around a subordinate fish named Tyrone, and his personal journey to become a dominant male in his community over Burt the Bully. Supporting fish characters who want to help Tyrone on his journey include Toni, his female friend, and Gilgamesh, a much older and wiser male with impressive firsthand knowledge of scientific concepts such as animal behavior, physiology, neurobiology, and more. Although reluctant to believe the seemingly tall tales of Gilgamesh at first, Tyrone learns to appreciate him and the scientific knowledge he shares. It is through this knowledge that Tyrone gains the confidence he finally needs to confront Burt (Figure 1). Care was taken to ensure *Fin-tastic Fish Science* communicated the same accurate scientific content as the journal article it was based on, but with a visual comic book approach to storytelling.

2.2 | Demographics

Data for this study were gathered from a large enrollment introductory biology course for undergraduate non-biology majors over the course of three semesters (Fall 2020, Spring 2021, and Fall 2021) at a large state university in the southern United States (Louisiana State University). General Biology I Lab for non-biology majors (BIOL 1005) covers basic biology and provides an introduction to the scientific method. Differences in participant demographics in sex/gender identity, race/ethnicity, academic year, or degree program were evaluated by analysis of variance (ANOVA), and across all three semesters no significant differences were detected (Table S1). Therefore, the three sections were considered one participant pool. All sections were primarily female, white, second-year psychology majors. Permission for student participation was granted (Institutional Review Board [IRB] exception approval, IRB #E11924) as well as approval from both administrators and course instructors. Exclusion criteria for the study included students who did not complete all questions in either the pre- or post-reading questionnaire.

2.3 | Assessment

Student participants were randomly divided using an open-source online randomizer into groups and given one of the four following treatments to read apart from their regular coursework activity: (1) no additional activities (control), (2) an additional primary research article as published in a scientific journal (Butler et al., 2018), (3) an additional brief "news"-type summary of the published journal article written by Rose Wayne and Karen Maruska for this study, or (4) *Fin-tastic Fish Science*, an additional full-length comic book created by the first author. Participants had 1 week to read the material on their own time and all sources contained the same scientific content focused on the neurobiology of social defeat in male cichlid fish. Participants completed identical pre- and post-reading questionnaires. The pre-reading questionnaires were administered 1 week before text distribution, and the post-reading questionnaires were administered 1 week after engagement with the respective text of each group. The pre- and post-reading questionnaire consisted of 28 questions divided into two categories: 14 perception questions to measure attitudes toward science engagement and 14 content questions to measure learning. Perception questions consisted of four different indicators as follows: time (questions 1, 2, 5), motivation (questions 3, 4, 5, 6, 11), medium (questions 9, 12, 13, 14), and background (questions 7, 8). Time indicators included questions such as how long it takes a student, or how long they would be willing to take, to read about science. Motivation indicators included questions such as how much students enjoyed, or were intimidated by, reading about science. Medium indicators included questions such as what format students preferred, or would prefer, to engage with science. Background indicators included questions such as whether students thought a strong background knowledge was needed to engage with science. The perception category contained multiple-choice and Likert-scale questions, and the content category contained multiple choice questions. Participation was voluntary; however, to encourage students to participate, they were offered bonus points applied to their course grade for successful completion of the pre- and

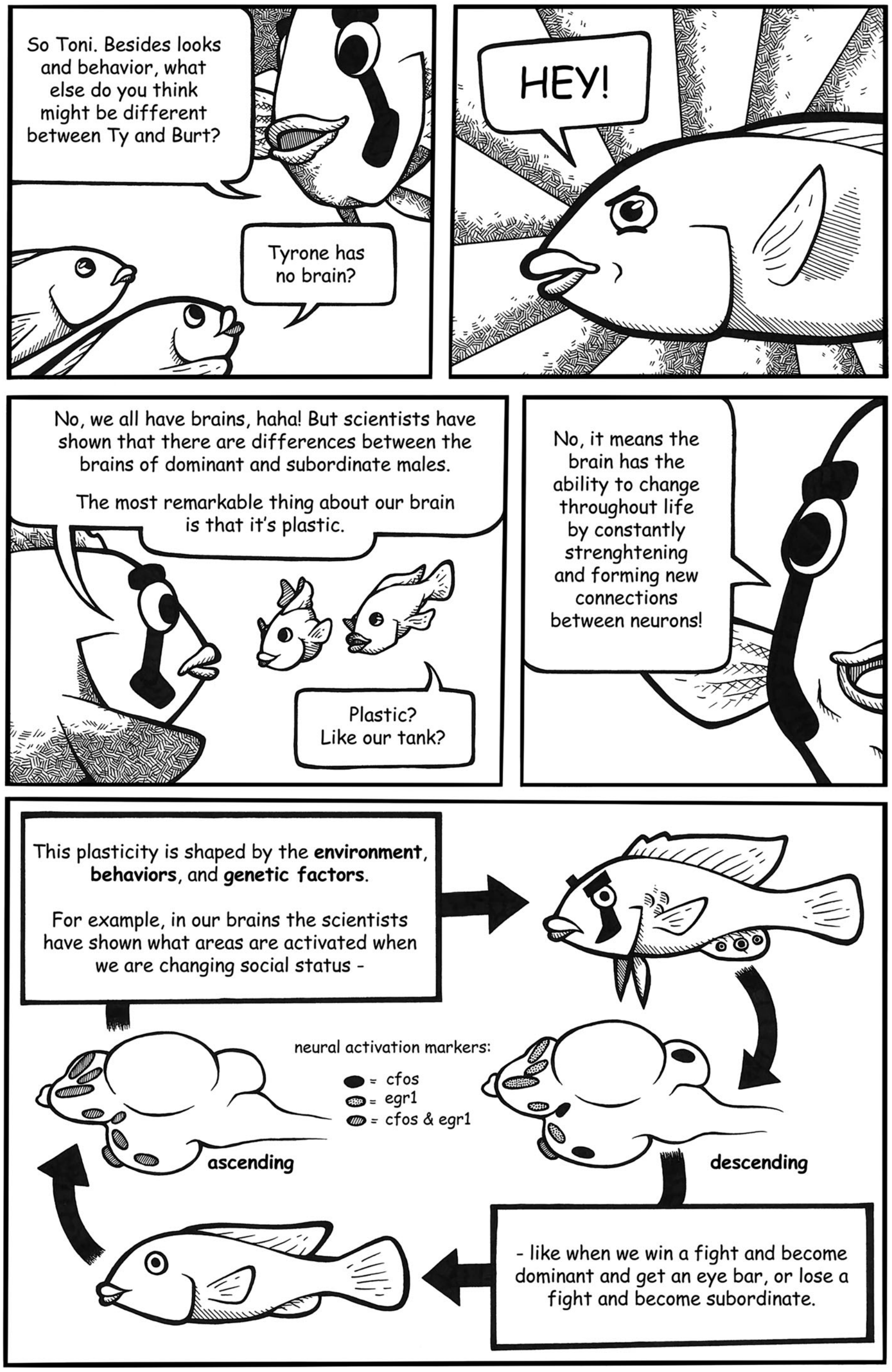

FIGURE 1 Example of comic art. A page from *Fin-tastic Fish Science* in which Gilgamesh explains scientific topics to Tyrone and Toni. For example, the physical differences between subordinate and dominant males in their species, *Astatotilapia burtoni*, as well as neurobiological differences shown through the use of the neural activiation markers, *cfos*. The comic contained the same scientific content as the published journal article by Butler et al. (2018) it was based on.

post-reading questionnaires. Bonus points were applied to one quiz grade if students completed both the pre- and post-reading questionnaire or selected to opt out of the study on the pre-reading questionnaire. Students were instructed not to collaborate with others or ask questions about the reading material during the experiment.

Evaluation of the instrument occurred over one semester prior to this study. The experimental design was conducted as previously mentioned above and pre- and post-questionnaires were completed electronically through the survey software Qualtrics. Findings from this pilot study demonstrated greater learning gains in students given the comic and news summary compared to the control and the original journal article. It also allowed us to refine our pre- and post-questionnaires to improve data collection.

A total of 536 students were enrolled in BIOL 1005 across the three semesters of this study with 353 students participating in this study. Of these, 109 were removed for opting out of the study or starting, but not completing, the pre- and post-reading questionnaires. A total of 244 students completed the pre- and post-reading questionnaires resulting in a participation rate of 45.52%. There were 68 students in the control group, 53 in the journal article group, 68 in the summary group, and 55 in the comic group. Pre- and post-reading questionnaires were completed electronically through the survey software Qualtrics (Qualtrics). All semesters of this study took place during the Covid-19 pandemic, when all courses on campus were conducted virtually. The pre- and post-reading questionnaire content can be seen in Table S2.

2.4 | Statistical analysis

All analyses were performed in SigmaPlot 12.3 (Systat Software Inc.) and Statistical Analysis Software (SAS) 9.4 (SAS Institute). The objective of these analyses was to assess knowledge gained after reading a comic book compared to more traditional texts and whether there was an increase in positive attitudes toward engaging with science. The data were analyzed in two different ways. To test how much students learned from their assigned text, learning gain was calculated from the content section of the pre- and post-reading questionnaire. Normalized learning gain was defined as follows: learning gain = (post-reading score − pre-reading score) œ (total score − pre-reading score) (Hake, 2002). Learning gain scores were calculated and then averaged across all content questions for each group. To determine whether learning gain averages could be combined across semesters, learning gain averages were compared using a one-way ANOVA followed by Bonferroni's test for post hoc comparisons. Only the control group exhibited a difference across semesters (Table S3), thus, this study used combined data from across all three semesters. To test if students' perception toward science changed based on assigned text, a generalized linear mixed model and a generalized linear model were performed on the perception section of the pre- and post-reading questionnaire. These models used a logit-link and binomial probability distribution, with group as a fixed effect and semester as a random effect. Models were performed with and without the random effect and the model combining semesters (without the random effect) was determined to be optimal by likelihood-ratio test. To examine internal consistency and give context to these results, Chronbach's alpha was estimated for each combination of treatment group and pre- and post-time period. Results of the pre- and post-reading questionnaire content can be seen in Table S4–S7).

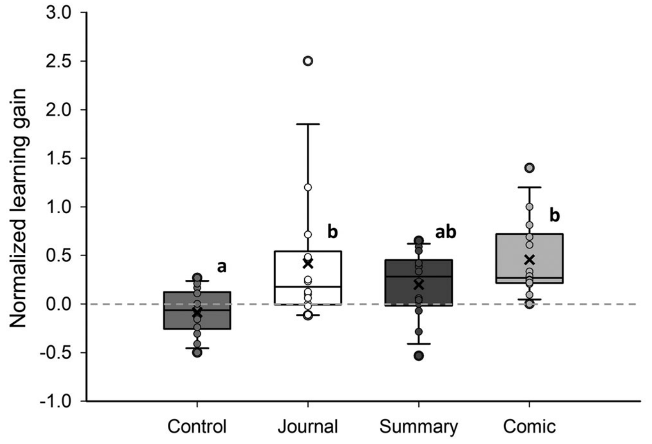

FIGURE 2 Learning gains show that students learned most from the comic and journal article. Learning gains based on pre- and post-reading questionnaires were greatest in students who read the comic or journal article. The lower and upper limits of the box represent the 25th and 75th percentile, respectively, and whiskers extend to the smallest and largest values 1.5× the interquartile range. Individual data points are plotted as filled circles, the median as a line, and the mean as a cross. Different lowercase letters represent significant differences ($p < 0.05$). Sample sizes: $n = 68$ control; $n = 53$ journal article; $n = 68$ summary; $n = 55$ comic.

3 | RESULTS

3.1 | Learning gain

Learning gain scores were highest among students who read the comic book, *Fin-tastic Fish Science*, and the journal group (Figure 2). Control group students had an average learning gain of −0.08 ± 0.22, journal article group students had an average learning gain of 0.42 ± 0.69, summary group students had an average learning gain of 0.19 ± 0.34, and comic group students had an average learning gain of 0.45 ± 0.39. Compared to the control group, students in both the comic ($F_3 = 4.24$; $p = 0.017$) and journal groups ($F_3 = 4.13$; $p = 0.020$) had higher learning gains. Students who read the summary article did not have a significantly higher learning gain compared to controls ($F_3 = 2.12$; $p = 0.474$). There were no significant differences in learning gain among the comic, journal, and summary groups.

3.2 | Student perception

3.2.1 | Time

Across treatment groups and time periods, Chronbach's alpha values were generally lower than acceptable (α from 0.70 for the fall comic and control groups post treatment to 0.62 for the comic pre group) suggesting that results may have

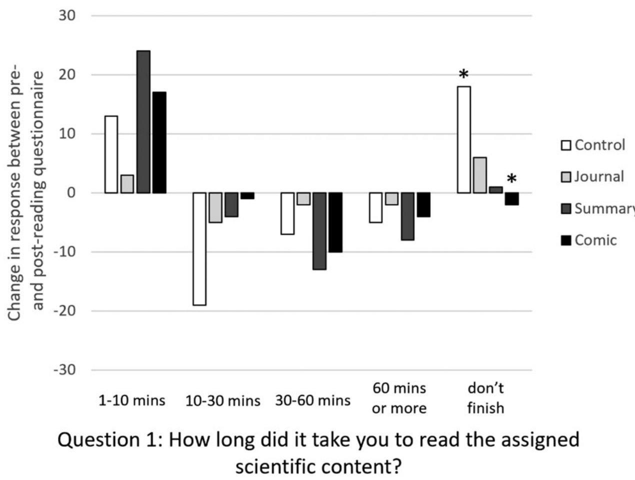

FIGURE 3 Directional change between pre- and post-reading questionnaire answers for perception questions related to reading time. Control group students were significantly less likely to finish the reading material than all other groups, as they did not receive a text to read. Comic group students were significantly more likely to finish the reading material than all other groups. Asterisks represent significant differences ($p < 0.05$).

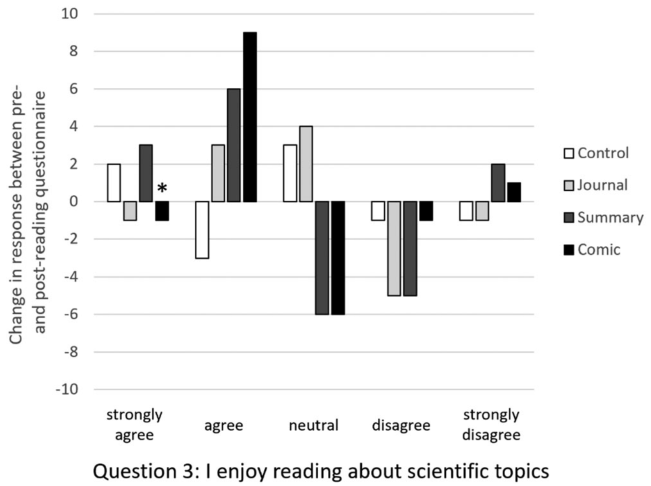

FIGURE 4 Directional change between pre- and post-reading questionnaire answers for perception questions related to enjoyment of science. Comic group students were significantly less likely to strongly agree with enjoying reading about scientific topics. Comic group students also expressed a nonsignificant increase in positive attitudes toward reading about scientific topics compared to all other groups. Asterisks represent significant differences ($p < 0.05$).

limitations in interpretability. When asked how often it would or did take students to read their assigned scientific text, the highest selected answer for the pre-reading questionnaire was "10–30 min" for all groups apart from the journal article group who selected "30–60 min." For the post-reading questionnaire, "did not finish" became the highest response for the control group, "30–60 min" remained the highest response for the journal article group, "10–30 min" remained the highest response for the comic group, and "1–10 min" became the highest response for the summary article group. In the control group, students responded "did not finish" significantly more often (Wald $\chi^2{}_1 = 228.90$; $p < 0.001$) than all other groups, likely due to receiving nothing to read (Figure 3). In the comic group, students responded "did not finish" significantly less (Wald$\chi^2{}_1 = 300.49$; $p < 0.001$) than all other groups (Figure 3). When asked how often students would be willing to spend engaging in self-motivated reading about scientific topics in the type of text they received, the highest selected answer for the pre-reading questionnaire was "a few times a year or less" for all groups. For the post-reading questionnaire, "a few times a year or less" remained the highest selected answer for the control, journal article, and summary groups. Although not significant, "about once a week" became the most selected answer for the comic group post-reading questionnaire, suggesting an increased willingness to engage with science in the future compared to all other groups. There were no differences among the groups when students were asked questions related to how long they were willing to spend reading about new scientific topics (highest pre- and post-reading response: 10–30 min).

3.2.2 | Motivation

Across treatment groups and time periods, Chronbach's alpha values were very high (α from 0.94 to 0.96 for all groups) indicating high consistency when interpreting results. When asked whether students enjoyed reading about scientific topics, the highest selected answer for the pre-reading questionnaire was "neutral" for all groups. For the post-reading questionnaire "neutral" remained the highest selected answer for the control, journal article, and summary groups. In the comic group, students responded "strongly agree" significantly less than other groups on the pre-reading questionnaire (Wald $\chi^2{}_1 = 4.20$; $p = 0.040$) (Figure 4). However, "agree" became the most selected answer for the comic group post-reading questionnaire, showing a nonsignificant trend of increased positive attitudes toward engaging with science compared to all other groups. When asked whether students were intimidated by scientific topics, the highest selected answer for the pre-reading questionnaire was "agree" for all groups. While not significant, for the post-reading questionnaire "agree" remained the highest selected answer for the control and summary groups, and "neutral" became the most selected answer for the journal and comic groups. When asked what most commonly prevents students from engaging with and learning about scientific topics, the highest selected answer for the pre-reading questionnaire was "the material is too difficult" for all groups except for the journal article group, who selected "I am not interested." For the post-reading questionnaire, "the material is too difficult" remained the highest response for the control group, "I am not interested" remained the highest response for the journal group and became the highest response for the comic group, and "the material is not interesting" became the highest response for the summary group. In the comic group post-reading questionnaire, students responded "nothing usually prevents me from reading" significantly less (Wald$\chi^2{}_1$ = 6.57; $p = 0.010$) than all other groups. There were no differences among the groups when students were asked questions related to whether they viewed science as a source of entertainment (highest pre- and post-reading response: "neutral"); and whether they learned new things while reading about science-related topics (highest pre- and post-reading response: "agree").

3.2.3 | Medium

Across treatment groups and time periods, Chronbach's alpha values were high (α from 0.86 to 0.96 for all groups) indicating high consistency when interpreting results. When asked what media students would prefer to use to discuss and share with friends about a scientific topic, the highest selected answer for the pre-reading questionnaire was "television/video" for all groups. In the post-reading questionnaire, "television/video" remained the highest response for all groups. However, the comic group saw a nonsignificant increase in the response "graphic art" compared to all other groups. In the comic group post-reading questionnaire, students responded "outreach events'" significantly less (Wald $\chi^2{}_1$ = 5.45; p = 0.020) than all other groups. There were no differences among the groups when students were asked questions related to what visual preferences students had when reading about science (highest pre- and post-reading response: "I prefer things with lots of visual aids"); what media students most commonly engaged with when learning about science-related topics (highest pre- and post-reading response: "television/video"); and what media students would prefer to engage with about science-related topics (highest pre- and post-reading response: "television/video").

3.2.4 | Background

Across treatment groups and time periods, Chronbach's alpha values were generally high (α from 0.89 to 0.95 for groups, except control group post activity, which was 0.77), indicating generally high consistency when interpreting results. There were no differences among the groups when students were asked questions related to whether a strong science background was needed to understand new science-related topics (highest pre- and post-reading response: "agree"); and whether they knew model organisms played an important role in scientific discoveries (highest pre- and post-reading response: "agree").

4 | DISCUSSION

The scientific community has long understood the value of using combined text and visuals for instruction, as seen with scientific illustrations (Ford, 1993). It has been proposed that abstract concepts in science, which are difficult to convey with just words, could also be more easily summarized by the language of comics (Farinella, 2018; Hansen, 2004; Tatalović, 2009; van der Sluis, 2021; Wright, 2002). Not only can comics be used to increase learning, but they can also be used to increase positive attitudes toward engaging with science. Several studies have demonstrated that the unique visual language of comics leads to better reading performance and retention, increased literacy, and more frequent reading (Carney & Levin, 2002; Krashen, 2004; Spiro et al., 1980). Storytelling woven throughout a comic can also be used to reframe content through a situational narrative, which may further improve understanding (Arroio, 2011; Avraamidou & Osborne, 2009; Suzuki et al., 2018).

Comics are a medium capable of visually portraying abstract scientific topics. The question we asked in this study was whether students would learn more and perceive engaging with science in a more positive light after reading a scientific comic book compared to more traditional written texts, a scientific journal article, or a popular science summary. Texts were distributed to students in an introductory biology course for nonmajors. The majority of students in this course were white female psychology majors in their sophomore year. This population is reflective of a significantly underrepresented group within science, technology, engineering and mathematics (STEM) fields and is a target audience for science outreach efforts (NCSES, 2023). Female readers comprise about 40% of comic readership in surveys of reading habits comparing male and female readers (OECD, 2010). Given the positive response to the comic in this study, comics could be an effective method to reach this targeted population and possibly others who are currently underserved by other methods of science communication (Freedman et al., 2022). However, there is the possibility these findings may not respond as well with other groups as there can be cultural differences in how the visual language of comics is read (McCloud, 1994). Comics can be combined with other media options (e.g., short audio and visual summaries, interactive media, and text summaries) to improve comprehension across demographic groups, including nonwhite, immigrant, and neurodivergent students not included in this study.

Students who read *Fin-tastic Fish Science* observed a learning gain equal to those who read a scientific journal article, suggesting that comic books are equally capable of effectively conveying scientific information as traditional texts. Students in the summary group, however, learned less, demonstrating that these types of popular science summaries can be less effective at conveying technical information. The control group was the only group that did not show any learning gain between pre- and post-reading questionnaires, as they did not receive a text to read. While students learned from the journal article, and despite an increase in open-access publication, most journal articles remain inaccessible to the public (Boudry et al., 2019; Hayes, 1992). Research summaries are one of the most popular forms of accessible texts, but findings of this study suggest that they may not be the best medium for learning (Ross-Hellauer et al., 2020). Similar to science summaries, comics are also easy to disseminate publicly (e.g., digitally, print publishing, and distribution of physical copies at events). However, they may be better communication tools for outreach as demonstrated by the high learning gain among students who read the comic. While comics in the last 30 years have become incredibly diverse with a wide variety of styles, there is still a stereotypical perception that they primarily appeal to children, must be humorous, and are not perceived as "valid literature" (CBLDF, 2019). As such, comics remain largely overlooked and underutilized, particularly within academia, as a communication tool to improve learning and increase engagement with science.

Not only did students who read *Fin-tastic Fish Science* learn as much as those who read a scientific journal article, they also showed a trend toward positive changes in attitude toward engaging with science compared to those who read other types of texts. Students who read the journal article took the longest time to read the material (30–60 min), the comic the second longest time to read (10–30 min), and the summary the least amount of time to read (1–10 min). This trend aligns with the expectation that the more difficult the format of the text is, the longer it takes students to read. Reading is an important indicator of academic understanding and success (Whitten et al., 2019). Notably, students who read the comic were significantly more likely to finish reading the material compared to all other groups, suggesting that they are a useful medium for maintaining engagement. This is reinforced by the follow-up question where students were asked how often they would be willing to spend time engaging in self-motivated reading about scientific topics in the reading medium they received. Students who read the comic were the only group to observe an increased willingness to engage with science in the future. The majority went from responding they would only engage once a year or less on the pre-reading questionnaire to responding they would be willing to engage about once a week on the post-reading questionnaire. All other groups responded they would only engage once a year or less on both the pre- and post-reading questionnaire.

The increase in engagement among students who read the comic is likely due to attitude shifts only observed in this group. On the post-reading questionnaire, comic group students' enjoyment toward reading about science increased and their intimidation toward reading about science decreased. They were also less likely to engage with science, not due to perceived difficulty of content, but rather because they were not personally interested. All groups reported television or videos to be their preferred form of engaging with science. However, students who read *Fin-tastic Fish Science* were more willing to engage with the medium of comics in the future compared to all other groups. While our findings were not as pronounced, they are in line with a study conducted by Lin et al. (2014), who also found that comic readers (83%) were much more interested in using the medium of comics in the future to learn more about the science of nanotechnology than text readers (71%).

Overall, these findings demonstrate that science comics are just as effective as traditional media, and more effective than some such as summaries, for learning. Comics also increase the likelihood of maintaining engagement and may improve attitudes toward science among biology nonmajors. The students involved in this study represent a population underrepresented in STEM, suggesting that, if utilized, comics could be a useful medium for science education and literacy outreach. Although these findings are promising, there are limitations and challenges to address regarding the creation and distribution of science comics as a form of outreach to improve science literacy among students or the public. *Fin-tastic Fish Science* is unique in that it was written and drawn by the same person. If a comic were to be created by a different writer and artist, it is important that both share the same vision for the final product. It is possible that during the process of translating a script into images, comic artists can distort the writer's vision by inadvertently adding their own elements, impairing the intended scientific communication to a reader (Eisner, 2008). It would be interesting for future studies to examine the impact of learning from existing science comics written and illustrated by scientists such as "Bird and Moon" by Rosemary Mosco or "Moistly Harmless" by Ethan Kocak compared to those created by artists engaging in science communication (Kocak, 2023). Traditional publication is an option for printing and distributing a science comic; however, it may be costly and takes a significant amount of time. If the goal is to enhance science literacy among the public, digital distribution is a free, quick, and more accessible format, as seen by the rising popularity of science web comics (Cham, 2002; van der Sluis, 2021).

Future studies should target different demographics (e.g., culture, age, and neurodivergence) to examine whether they also learn more from or perceive engaging with science in a more positive light after reading a scientific comic book. While participation in this study was voluntary for students, and not a substitute for any coursework, student familiarity with frequent undergraduate-level reading and research—despite being non-majors—may result in initial attitudes toward science being different than individuals outside of academia. Would members of the public who read a comic see similar positive changes in learning, engagement, and perception toward science? Future studies could also benefit from measuring participant engagement with science over a longer period of time, rather than just measuring attitudes via a questionnaire asking participants about their willingness to engage with science in the future. Would participants who read the comic and reported an increased willingness to engage with science in the future follow through with this sentiment in some measurable way? We are currently developing experiments to investigate these questions.

4.1 | Assessing materials

This paper assesses a publicly available comic book entitled *Fin-tastic Fish Science* that was written and drawn by the author, C. Rose Wayne. The work reported here uses this comic to assess how a science comic can affect student learning and attitudes toward engaging with science. This is in no way to be construed as a promotion of this comic, especially to the exclusion of others. Our findings support the idea that comics, in general, can be effective for learning and increasing engagement. *Fin-tastic Fish Science* can be accessed and read for free online at the following website: https://repository.lsu.edu/biosci_maruskalab/1.

AUTHOR CONTRIBUTIONS

C. Rose Wayne: Conceptualization; data curation; formal analysis; investigation; methodology; resources; visualization; writing—original draft; writing—review and editing. **Michael D. Kaller**: Data curation; formal analysis; visualization; writing—review and editing. **William E. Wischusen**: Conceptualization; investigation; methodology; writing—review and editing. **Karen P. Maruska**: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; supervision; visualization; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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