

Mystery of the Monkey Flower: Using a Comic in Science Curriculum and Teaching to Promote Student Engagement

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ABSTRACT: Engaging curriculum that invites all students to learn science and promotes interest and participation in STEM (science, technology, engineering, math) is a goal of science education. Comics that have accurate science content, interactive features, and characters with whom students can relate offer accessible and interesting STEM learning materials distinct from a science textbook. This mixed-methods study investigated the impact of using a comic embedded in a high school biology curriculum to study student engagement and teacher and student perceptions of using this type of learning material. Findings indicated student engagement at behavioral, emotional, cognitive and agentic levels (Sinatra et al., 2015). Students actively participated in learning by exploring the comic, generating robust classroom discussion regarding science and issues related to race and racism in science. Teachers and the majority of students agreed that the comic helped students learn the science in the unit and better understand the role of field research. The synergy between embedded comic and curriculum provides a model for curriculum creation and use. The study engenders additional research questions in science education, including literacy in content learning, connecting to careers in STEM, and measuring science learning through a comic.

INTRODUCTION

Creating engaging science curriculum that invites all students to learn science has long been a goal in science education and gets at the heart of equity in science learning. “Inclusive instructional strategies encompass a range of techniques and approaches that build on students’ interests and backgrounds so as to engage them more meaningfully and support them in sustained learning” (National Research Council, 2012, p. 283). Science curriculum and pedagogy have been known to portray science as “dogmatic, authoritarian, impersonal, and even inhuman to many students. It also portrays science as being much more difficult than it is, and scientists as being geniuses that students cannot identify with. It alienates students from science” (Lemke, 1990, p. xi). Using comics shows potential to counter these views, promote interest and broaden participation in STEM (science, technology, engineering, math) (Elliott, 2015), and

engage students in learning (Akcanca, 2020; Cantor, 2014; Mamolo, 2019; Matuk et al., 2021; Mignone et al., 2016; Shurkin, 2015).

Comics are characterized by a set of frames in which images, text, and the relationship between frames are important. Readers fill in the gaps between frames to actively make meaning and create the story (Akcanca, 2020; Tatalovic, 2009). Comics come in different lengths and levels of complexity: comic strips with just a few frames, comic books with a developed narrative, and graphic novels that have a complex plot and developed set of characters. The form of storytelling in science comics differs from that of textbooks or typical classroom materials, with the language of science comics bridging everyday and academic language (Akcanca, 2020), capturing readers’ interests and sharing essential information about complex scientific and social issues in an

enjoyable way (Bouchard et al., 2020). Effective stories can bring relevance and interest to a phenomenon, connecting the story to clear and accurate scientific information (Akcanca, 2020). Reading a comic and engaging in the sense making of the story can reinforce the practices of asking questions, writing explanations, and communicating scientific ideas. In addition to offering a fun and exciting way to communicate science, effective science comics can offer science content and relevant representations of scientists (Tatalovic, 2009).

Gaps in Science Comic Research. Accurate, well-designed comics that focus on concepts appropriate for the intended grade level can provide teachers with a useful instructional tool (Mignone et al., 2016; Roswati et al., 2019). Ulta (2015) found that embedded concept cartoons within a context-based learning approach curriculum supported remedying eighth graders alternative concepts of chemical bonding. Spiegel et al. (2013) noted that comics supported engagement of ninth and tenth grade students with low science identity. However, little research has looked at the synergistic way comics can work embedded within a science curriculum. Our project adds to the literature by studying a comic embedded in a Next Generation Science Standards (NGSS)-designed, project-based, high school life science curriculum. This study explored the research questions: *What are students' and teachers' perceptions of a comic that is embedded in a curriculum? How did teachers use the comic in instruction? How did students engage with the comic?*

Project Comic. The comic, *The Mystery of the Monkey Flower* (Jackson et al., 2021), is part of a 7-week high school project-based curriculum, *Health in Our Hands: Mystery of the Monkeyflower* (Morales et al., 2022), created in a National Institutes of Health and National Science Foundation funded project that is designing and testing learning materials that blend school and community learning experiences to teach genomics and evolution (Figure 1). The educational science-themed comic includes fictional characters and a story that communicates science and educates readers about a non-fictional scientific concept (Tatalovic, 2009), supporting student engagement and introducing STEM careers.

The comic is embedded in a unit in which students grow monkeyflower plants in their classroom, and use the plants to collect data and conduct research (Figure 2). Instead of a science textbook, students use the comic as a guide that leads them through the unit (Table 1). The comic introduces students to the interesting world of scientific field research through the eyes of two young researchers of color, Maia and William, who are studying monkeyflower plants in nature. The comic has four modules designed to be read at specific points in the unit storyline and revisited for relevant information as students take part in sensemaking discussions. By

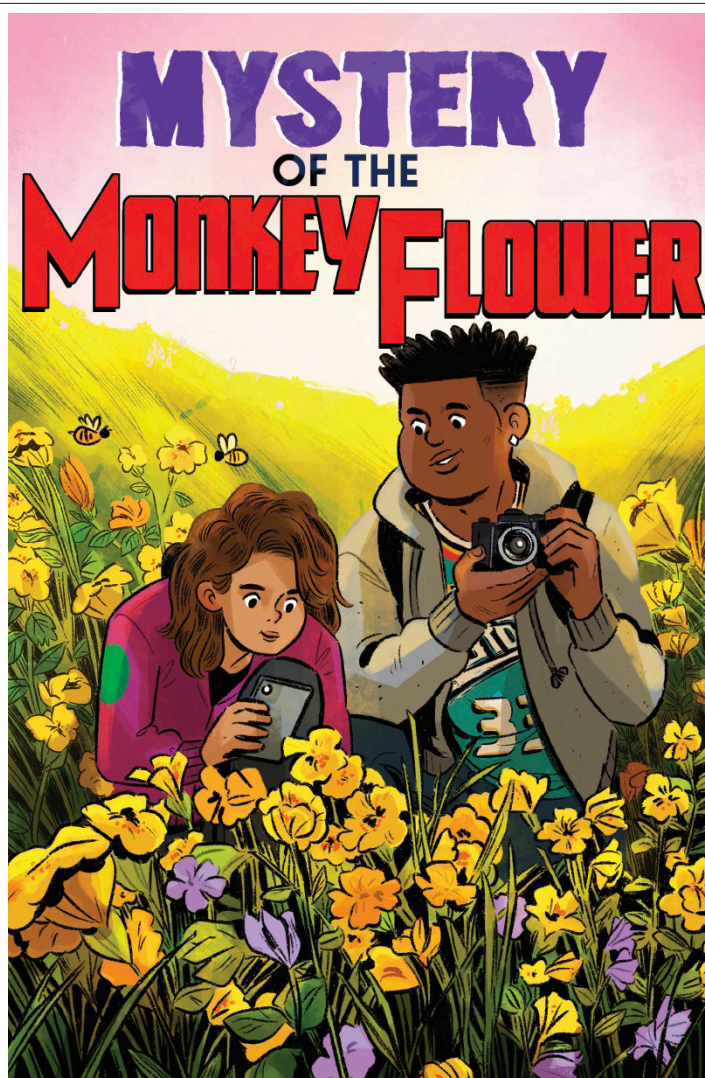


Figure 1. Cover of the *Mystery of the Monkey Flower* Comic Book.

interacting with the plants growing in their classroom and the comic book, students figure out what causes similarities and differences between organisms using scientific principles in gene-environment interactions and natural selection.

The storyline of the comic and students' experiments are based on the research of a plant biologist from a Midwest university who collaborated with science education researchers to ensure accurate science content in the curriculum and comic (Tatalovic, 2009). The team consulted periodically with the project's community partnership, which includes representatives from education, health, and community-based organizations. Community partners reviewed several draft drawings of the main characters and discussed how the comic could support exploration of race, culture, and equity to promote broadening participation in STEM. This attention to how scientists are portrayed and how comics represent science and scientists attends to issues of equity in science materials (Tatalovic, 2009). Suggestions were incorporated into the initial draft, which was piloted by middle school teachers. Feedback from this first pilot suggested

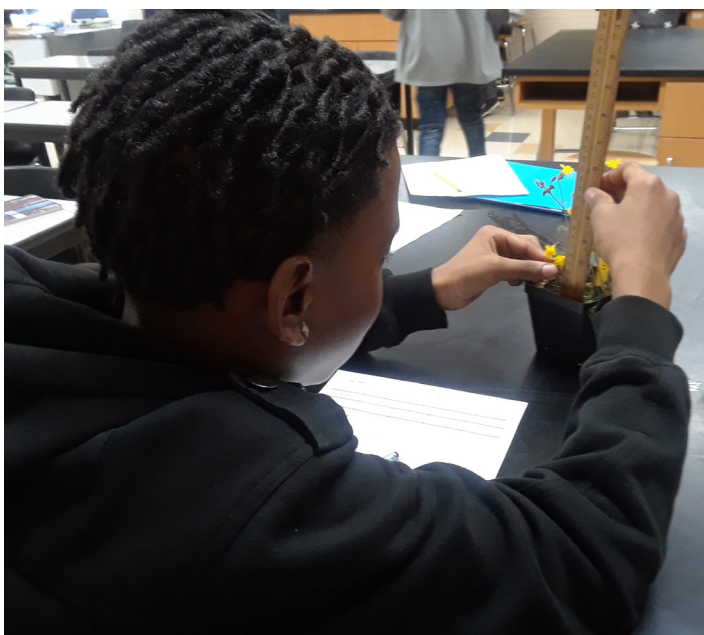


Figure 2. Student measuring a monkeyflower plant.

that students appreciated the story of the young researchers and noticed the diversity of races and ethnicities represented among the characters. Community partners suggested more details about characters' features and dress to attend to diversity and inclusion. The comic was finalized based on this pilot implementation and community partner feedback. The final version included a new section with examples of diverse researchers involved in different kinds of genomic research.

Engagement in Science. Sinatra et al. (2015) note that the science education research community has not agreed on a definition of student engagement in science. They propose four domains of engagement, which were applied in this study: behavioral (i.e., active participation in learning through discussions), cognitive (i.e., expending cognitive effort beyond that required to understand a concept), emotional (i.e., negative or positive emotional reactions, such as enjoyment, to a science topic) and agentic (i.e., communicating to the teacher their preferences/interests and the teacher modifying the flow of lessons to include those preferences/interests). Sinatra et al. (2015) distinguish between micro (individual) and macro (groups of learners) levels of engagement. Researchers agree that these domains of engagement often overlap (Alrashidi et al., 2016).

Cognitive engagement, although linked, is different from content learning. Students' mastery of content is typically measured through content specific assessments. Cognitive engagement includes factors such as students' intrinsic motivation to learn content (Lam et al., 2012) and the effort students expend to understand a topic (Sinatra et al., 2015). Academics such as Ainley (2012), Sinatra et al. (2015), and Skinner and Pitzer (2012) agree that student engagement supports positive learning outcomes and long-term partici-

pation in schooling and can also serve as positive and protective factors, especially for young people who may be at risk for dropping out or underachieving in school.

METHODS

This mixed-method study was carried out in two Midwest urban high schools in winter 2021. Teachers received all supplies and materials needed to implement the newly-created high school NGSS-designed, project-based learning science unit that included the embedded comic. Teachers participated in ongoing professional learning and received individual support. They were provided the comic in an online format and it was also available to download for printing.

Two teachers enacted the unit in full, using the comic in their classrooms with 168 students in grades 9-11. Study leaders obtained parental consent and youth assent from all participants, in accordance with Michigan State University IRB (human subjects approval MSU IRB #X14-378e). Teacher participants included Michael (pseudonym), who had over 20 years of experience teaching science, and Linda (pseudonym), with 6 years of experience teaching science. Linda had more experience with the NGSS as a pre-service teacher and master's student. Michael's school had a majority Black/African American racial makeup (75%) and 15% White population. Linda's school was majority White (56%) and 27% Black/African American. A small percentage of students in each school were Latinx (4% and 8% respectively).

Data Sources. Table 3 lists the data sources used to answer the research questions. The study used various sources of data to triangulate the findings and address the limitations of self-report data, including the potential for socially desir-

Table 1. *Mystery of the Monkeyflowers Unit Outline.*

Learning Set	Driving Questions	Students Figure Out	Comic
1	How are the traits of the two varieties of monkeyflowers similar or different?	The different parts of the monkeyflowers, and the similarities and differences in traits of organisms	Read Module 1
2	What causes the similarities and differences between monkeyflower traits?	The structure and function of DNA, the relationship between DNA and proteins, and the mechanisms of genetic variation	Read Module 2 and 3
3	How does changing the environmental conditions affect the survival of different monkeyflowers?	The effect of environmental conditions on the growth and survival of organisms	Read final Module 4
4	How do the differences between monkeyflowers happen over time?	The process of natural selection	

Table 2. Data Collection Tools with Questions Identified for Each Type of Engagement.

Type of Engagement	Student Focus Groups	Student Surveys on a 4-point Likert scale	Teacher Interviews
Behavioral	- Do you think the comic makes science interesting and engaging? Why or why not? - Did the comic help you participate in class discussion and activities? How? Why or why not?	N/A	- On a scale of 1-10 (1 = <i>does not work</i> to 10 = <i>it worked super!</i>), do you think the students liked the comic and found it engaging? Tell me more. - How did you have the students read/engage with the comic? Did they read it aloud, to themselves? In a play? Did students read it on their own? In class? Outside of class? - Did you hear the students refer to the comic during other times in the unit? For example, when they were doing other activities in the unit, did they ever mention the characters or something about the comic?
Cognitive	Did the comic help you figure out more about the plants? If yes, how? If not, why do you think so?	- The comic was easy to read. - The text and images helped me learn about... - The text and images both helped tell the story. - The comic helped me understand how traits evolve over time through natural selection. - The comic helped me figure out how genes and the environment interact. - The science terms used in the comic were explained so that I could understand. - I understood the story the comic was telling. - I understood all the words in the comic. - The story and the comic were confusing.	- On a scale of 1-10 (1 = <i>does not work</i> to 10 = <i>it worked super!</i>), do you think the comic and its storyline engaged and drew students along in the unit? Tell me more. - On a scale of 1-10 (1 = <i>does not work</i> to 10 = <i>it worked super!</i>), do you think the comic supported students in figuring out the phenomenon (gene-environment interactions)? Tell me more.
Emotional	- Did you like the comic? Why or why not - What do you like about the comic? Tell me more - What don't you like about the comic? Tell me more - Did you like the characters? Why or why not? - Did you see yourselves in the comic? - Did the comic make learning science fun and interesting? How? Why or why not?	- I liked how the characters looked. - I liked reading the comic in sections. - I would like to use comics like this one in other science classes. - The comic was interesting. - The comic was boring. - I liked reading the comic online.	- Did you think students of color saw themselves in the comic? - Did they like the characters? Did they relate to the characters? - Did they notice the diversity in the characters? - If they don't have anything to say, probe with: did they notice the main characters were scientists of color? Tell me more.
Agentic	N/A	N/A	- Were there any challenges with using the comic? If so, what were they? - Follow up with what we learned about some concerns about the comic with regard to race and the use of the term monkeyflower.

able responses. In this study, self-report student information was important for the “fine-grained assessment of mental processes, including students’ motivation, emotions, cognitive strategies, and metacognition during learning” (Pekrun, 2020, p. 191). Student focus group and teacher interviews supported the findings and added depth of information to student surveys (see Table 3).

Teacher Interviews. Post-enactment, the two teachers participated in two, 1-hour, individual Zoom interviews to answer questions about student engagement. The

transcriptions were coded by the lead author to identify themes related to the research questions. The team met to review and discuss findings.

Teacher Discussions During Professional Learning (PL).

Recordings and notes from weekly online professional learning sessions were reviewed. Comments were coded to identify themes related to the research questions.

Student Focus Groups. In-person student focus groups were conducted in Linda’s (two focus groups) and Michael’s (one

Table 3. *Data Sources.*

Data Source	Data Collection Method	Sample Size	Participants
Teachers	- Two, 1-hour interviews - Professional Learning sessions/notes	2 teachers	Linda (School A) Michael (School B)
	- Classroom observations - Teacher communications - Posts on interactive learning platform		
Grade 9-11 Students	1-hour focus groups	14 students 3 groups	Linda's and Michael's students
	Online Survey	28	Linda's students

focus group) classrooms with a total of 14 students. The recordings were transcribed and the first author analyzed the transcriptions for themes.

Student Comic Feedback Online Survey. Students in Linda's classroom ($N=28$) responded to an online survey about the experience of using the comic to learn about science. The project team created the survey to ask about recall of characters and main ideas and concepts identified in research as relevant for the study, including language and engagement (Roswati et al., 2018), interest in the materials (Wiseman et al., 2021), enjoyment (Hanson et al., 2017), and overall satisfaction (Mamolo, 2019). Questions included yes/no options, short answers, and ratings along a four-point Likert scale (1 = *strongly disagree* to 4 = *strongly agree*).

RESULTS

Data were triangulated to answer the research questions (Fredricks & McColskey, 2012). Descriptive statistics from the student survey responses (See Figures 3 and 4) are presented along with quotes from student focus groups, student survey responses, and teacher interviews to place the results in context.

Teacher and Student Perceptions of the Comic Book.

Overall, the teachers liked the comic and liked using it. Michael stated, "*I think it's a darn good idea...[for] a couple of [students] comics is what they live for.*" Linda stated, "*The kids enjoyed it. They thought it was cool that we were using a comic, because well, they've never used a comic before.*" Both teachers appreciated the comic and, especially welcomed finding different ways to engage the students with science.

Student survey responses (Figure 3) and focus group discussions revealed their perceptions of the comic. Over one-half of the surveyed students agreed that they liked reading the comic in sections ($n=14$, 61%). Only about one-third enjoyed reading the comic online ($n=9$, 39%), possibly, because as Linda mentioned, "[the comic] was hard to read on

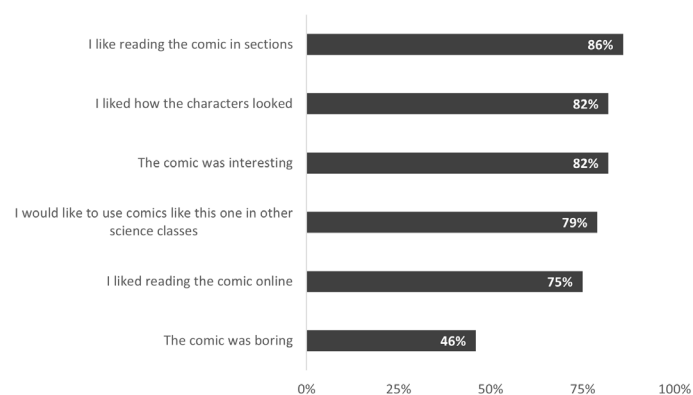


Figure 3. Students' perceptions of the comic book (percentage agree and strongly agree; $N=28$).

the screen because of the kids' Chromebook size." Students stated in focus groups a desire for physical copies of the comic to refer back to. Teachers Linda and Michael agreed that hard copies in the classroom might be helpful.

Students generally agreed the comic was easy to read ($n=17$, 74%), an opinion also heard in the focus groups. Students stated that the comic was "*easier to understand*," and "*better than reading a book or watching a video.*" One student "*liked that the comic had some challenging words in the book.*" In contrast, one student wrote that "*it could be confusing at times...[I] couldn't understand it and couldn't tell where to read next.*" The two students who reported being confused read comics for fun, suggesting that the confusion did not come from general lack of engagement with comics, but with something specific to this particular comic. Students in the survey and focus groups wished for more than two main characters and asked for a "*background story to the characters.*" One student suggested that "*The characters tried too hard to be relatable*" and another that "*the characters may be trying too hard to convince us that this unit is much more fun than we thought.*" Overall, students had positive perceptions of the comic as a tool to learn science, and they provided ideas about how to make the comic more engaging.

Teachers' Use of the Comic in Instruction. Discussions in PL and interviews revealed that teachers assigned students to read the comic to themselves. However, worried that not all students were reading it, and therefore not fully benefiting from the resource or classroom discussions, Linda used a theater style with students playing the comic characters. Michael reported that students in his class were less interested in reading the comic aloud; he created questions for students to answer to measure reading progress.

Teachers referred to the comic during class activities, noting that this strategy supported students in figuring out the unit phenomenon. Michael stated,

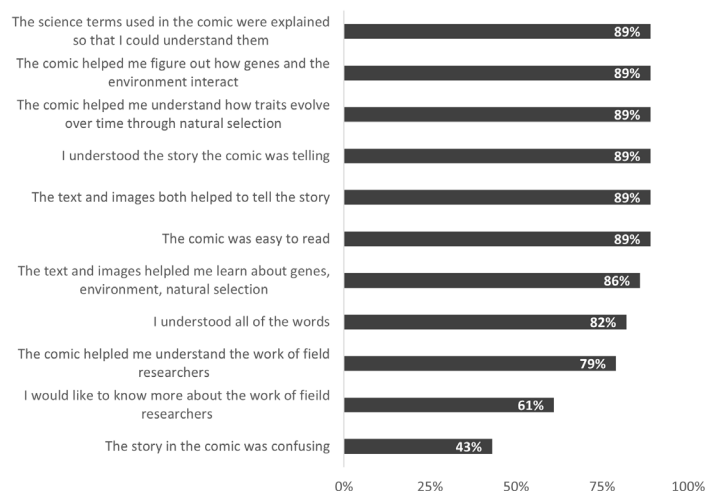


Figure 4. Students' perceptions of how the comic book helped them figure out the phenomenon (percentage agree and strongly agree; $N=28$).

[During] the protein synthesis, where I referred back to the comic...it helped to have them figure out that these guys [in the comic] are doing this in the lab, whereas I'm able to do this right here at my table, and I can do the same thing.

Both teachers used the comic to support learning, referring students back to different sections as they engaged in the science unit.

The main challenge that teachers discussed during professional learning was as Michael stated, "*getting [students] to actually read it.*" Linda and Michael agreed that students who paid attention in class and who read the comic found it engaging. Michael rated student engagement "*8 (out of 10), but for those that didn't read it, probably a 4.*" The consensus was that many found reading generally difficult, which initially made them resistant to reading the comic. To address this challenge, teachers shared ideas about ways to scaffold the comic for different levels of readers, including the teacher reading the comic out loud and students acting out different roles.

Student Engagement. Fredricks et al. (2004) noted student engagement (behavioral, cognitive, and emotional) were not isolated dimensions and that the dimensions are often interrelated. Therefore, some of the examples identified under one dimension of engagement would most likely fit under more than one kind of engagement.

Behavioral Engagement. Behavioral engagement, often observable, can include efforts students put into their learning in and out of the classroom. Evidence of behavioral engagement was gathered from teacher interviews and student focus groups. There were no student survey questions that

asked about behavioral engagement. In one of the focus groups, one student stated,

[W]hen I am out in the world or outside the school I can actually pay attention to plants and flowers and tell if it's healthy or not, if it's going to die or not, if it's good or not...plants tend to grow and tend to improve and die based on their environment, animals, and the stuff around them.

In another focus group, a student said it helped them, "*...recall back to it. Like if we were doing an assignment and they asked a question like how did William and Maia do this, and then we would look back to the comic and find our answer.*"

Cognitive Engagement. Involvement and willingness to learn about the science topic and field research, was indicated in both survey and focus groups. Figure 3 shows that the majority of students surveyed agreed that the comic helped them to learn about genes, the environment, and natural selection ($n=16$, 70%); understand how traits evolve over time through natural selection ($n=16$, 70%), and figure out how genes and the environment interact ($n=16$, 70%). One student wrote, "*I liked how they helped me understand the [plant] and...how the [plant] develops.*" In focus groups, one student stated that the comic "*helped us understand a little better...the visuals in the comic helped me connect with the plants in the classroom.*" Almost half of students ($n=10$, 43%) agreed or strongly agreed on the survey that the comic helped them understand the work of field researchers and a few ($n=5$, 22%) that they would like to know more about the work of field researchers. All of the students in the focus groups found the idea of field research interesting. One student stated, "*I think it would be cool to do what Maia and William do,*" while another stated, "*I didn't know [field research] was pretty interesting...seeing the characters in there doing a job that you didn't know anything about.*"

Emotional and Agentic Engagement. Emotional engagement includes both positive and negative reactions. Table 1 shows the majority enjoyed the comic ($n=15$, 65%) and almost one-half agreed or strongly agreed that the comic was interesting ($n=11$, 48%), writing that "*It was a fun way to learn*" and "*this comic personally gave me a click that sparked my curiosity.*" In focus groups, one student stated, "*the comic book put a lot of vibrant and more creative vibes to the story instead of just looking at words, instead of just listening to the teacher talk.*" Students enjoyed the style of art, "*the colors and the pictures,*" and "*[the] details in the pictures... the little creatures.*" The majority of students liked how the characters looked ($n=19$, 70%), with one student writing that the best thing about the comic was "*The way that characters looked like me.*" In the focus groups stu-

dents said, “*we could relate to [the characters].*”

Teachers noted that the comic made the students laugh, suggesting emotional engagement. Linda stated, “*they thought William was kind of the goofy guy and...They did laugh with the jokes,*” especially the banter between the characters. In the comic, the characters send messages to the students with scientific questions for them to work to answer. Linda stated, “*They also liked getting the ‘email’ from Maia.*”

Three students (13%) reported on the survey and one in the focus group that the comic was boring, writing that the comic was “*pretty predictable*” and that they “*didn’t like how they talked in the same place,*” perhaps hoping for different settings, and wishing for more dialogue and less descriptive text. A student in the focus group said that the comic “*disengaged me in the learning,*” explaining that there was “*no back story just talking about the flowers the whole time*” and asked for a “*connection to their childhood, how they got interested in the plants.*”

Agentic engagement (i.e., when a student actively contributes to and indicates preferences about the flow of instruction and teachers, in turn, respond by making changes that reflect those student preferences; Reeve & Tseng, 2011), arose in both teachers’ classrooms. The data indicated places where both agentic and emotional engagement were taking place. Examples of students’ emotional (both positive and negative reactions) and agentic engagement arose in both teachers’ classrooms. A few students in Linda’s class who identified as Black/African American raised a concern that the plant’s name was a racial slur. Concerns were discussed in PL and teachers were encouraged to validate students’ feelings and discuss the history behind the name of the plant; i.e., some varieties have distinct shape markings that make them look like the face of a monkey. The discussions helped reduce students’ concerns. Michael stated, “*I think it helped them a lot at that point, ‘cause at the beginning, when we first introduced the comic and the flowers, they automatically drew a conclusion. Not all of them but a couple of them.*” As a result of conversations with teachers, administrators, and community partners, the project team drafted a letter for parents that explained the unit along with a picture and history of the name of the plant. This situation also surfaced emotional engagement as the name initially brought about negative emotions for the students.

DISCUSSION

This study contributes insights into using a comic as part of a science curriculum. Teachers and students, overall, shared positive perceptions of using a comic in a science class. Teachers found various ways to support their students in reading the comic and using it to support students’ science learning.

Significantly, student engagement through a comic embedded in and working synergistically with a high school biology unit was observed at behavioral, cognitive, emotional, and agentic levels (Sinatra et al., 2015). Students actively participated in their learning by exploring the comic and engaging in robust classroom discussions not only around the science topic, but around issues related to race and racism. This is especially relevant to supporting productive discourse in a civil society. Teachers and students enjoyed the comic and most students connected with the characters and enjoyed reading the story. Teachers referred to the comic to support student understanding and noted students’ interest in communicating with the comic characters. Students referred to the comic to support their understanding of science and to better understand the plants they were growing and experimenting with in the classroom. Reading about the characters’ experiences encouraged students to ask questions about their environment and to connect their own lived experiences to the comic characters. Students personalized their learning by connecting what they were learning in the comic and unit to what they saw and experienced outside of the classroom. Because students brought up their discomfort with the plant’s name and actively sought out clarification, the teachers modified their instruction to meet the needs and preferences of their students, and the researchers crafted the parent letter. Data from this preliminary study show that the comic and curriculum worked synergistically to promote student engagement.

Lessons Learned. Comics are a promising, practical strategy to engage students in science education. The use of a comic provides a different visual way to present science to students who may be reluctant to read or have difficulty reading. As described above, the study emphasized the importance of including as many audiences as possible in the design and testing of an educational comic. Ideally, the design team itself would include more members representing the diversity included in the comic characters. The design and testing process considered accessibility and the comic was accessible in various forms (e.g., readable online, downloadable for printing in color or black and white). However, we learned that the online version presented some access issues on a Chromebook and students preferred holding the comic and reading the print version. Thus, in future iterations, a class set was printed for each teacher. Finally, we would have done more to prepare teachers and families for the ethical issues embedded in the comic story. By designing the main characters as field researchers of color, we hoped to broaden students’ ideas about who gets to participate in the scientific endeavor. Even the name of the plant, monkeyflower, raised questions in class about why one of the characters was Black.

Our study findings raise additional questions about using

comics in science education, including students' interest in and skills to read the materials, using comics to connect careers in STEM, and measurements to understand the level of science learned through a comic. Teachers reported that they measured student learning in various ways (e.g., students offering scientific explanations), but since student engagement, and not student learning, was the focus of this investigation, this study did not include tools to measure student content learning. Future work could include developing NGSS-aligned, 3D assessments to measure student learning before and after exposure to this unit.

The synergistic connection between the embedded comic and curriculum materials provides a model for curriculum creation and use. The comic showed students of color as science researchers to engage students in studying genetics and environmental interactions and expand their ideas about who gets to do science and where science takes place. This fun, “vibrant,” and interactive way to learn is freely available online along with all curricular related materials for researchers and educators.

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Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

Website Access to Curriculum

The MoM unit is open-source and accessible free from the CREATE for STEM Institute-Health in Our Hands website (<https://hioh.education/high-school>). Users can download the curriculum, get a supply list, view videos on equipment set up and plant care, and order free monkeyflower seeds from Dr. David Lowry.

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ABBREVIATIONS

NGSS: Next Generation Science Standards; PL: Professional Learning; SEPA: Science Education Partnership Award; STEM: Science, Technology, Engineering, Math

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