Alex Romagnoli, Judith Bazler, and Meta Van Sickle

Science Education and the Graphic Novel Connection: Pre-Service Teachers and the Creation of Graphic Novelettes

Abstract

This article outlines research that explored how pre-service science education teachers drafted multimodal artifacts, namely graphic novelettes (short versions of graphic novels) to help explain science concepts to varying grade levels. The research methodology and collaboration of the project, which included both Science Education and English Education professors, is first shared. The very nature of this collaboration informed the study's structure and implementation. The data gained from this study are then presented with an emphasis on how the creation of graphic novelettes by pre-service Science Education teachers facilitated the learning of scientific concepts while privileging the literacy skills students learn in all of their classes. Samples of student work are shared focusing on both the affordances and constraints of having students create multimodal content in order to better learn scientific concepts. Finally, the implications for science educators are presented and suggestions for future studies are asserted.

Introduction

Exploring rigorous and promising new methods of teacher preparation in science education reflects an understanding that in order to address the Next Generation Science Standards (NGSS), there needs to be an expansion of possibilities when interacting with texts. The NGSS state that, "reading in science requires an appreciation of the norms and conventions of the discipline of science" (NGSS Lead States, 2013). Furthermore, because, "Every effort has been made to ensure consistency between the CCSS [Common Core State Standards] and the NGSS," (NGSS Lead States, 2013) the Common Core's recognition of integrating multimodal texts is crucial to future science teacher preparation. Of particular note is Common Core Reading Anchor #7 which requires students to, "Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words" (National Governors Association Center for Best Practices & Council of Chief State School Offers, 2010). This focus on diverse forms of media is the purpose of this study.

Keywords: Graphic Novels, Visual Literacy, Science Education, Science Methods, Multimodality, Teacher Preparation

The use of graphic novels in educational contexts has become more mainstream in the past decade with much of the current literature focused on the area of Language Arts (Carter, 2007; Eckard, 2015; Morice, 2002; Schwarz, 2006). However, this established trend of focusing the potential of multimodal texts and "sequential art" (Eisner, 1985) in English courses accesses only a portion of the potential that graphic novels can provide in educational contexts. Other disciplines have already recognized this potential including mathematics (Reilly, 2015) and Social Studies (Christensen, 2006).

Science has also begun to recognize the importance of utilizing graphic novels with Tatalovic (2009) stating, "it appears that scientists and educators are becoming more aware of the appeal that comics hold for young people and are starting to use them more as a vehicle to communicate scientific ideas" (p. 4). The support for graphic novels in science education is also supported by other researchers (Brozo & Mayville, 2012; Jee & Anggoro, 2012) with an emphasis on supporting students in understanding complex scientific principles through multimodal texts.

This study involved the creation of graphic novelettes by preservice teachers in three elementary science methods classes. The novelettes (shortened graphic novels) were designed for inclusive elementary classrooms where preservice teachers utilized content based on the New Jersey Core Curriculums Content Standards for science. The novelettes are intended to be used as text materials to support classroom instruction in science for all students in inclusive classrooms. Each novelette was related to a curriculum unit that was also written for the class.

Graphic Novels

The creation of graphic novels, comic books, comic strips, and other forms of "sequential art" (Eisner, 1985) is traditionally collaborative in nature. Even in the most popular genre of graphic novels, the superhero genre, collaboration has been the key to producing powerful stories and enduring themes in a consistent manner (Romagnoli & Pagnucci, 2013). Because this study is collaborative in nature, with pre-service elementary education teachers constructing their own "graphic novelettes" about a topic in science education, the organization of the content is of paramount importance.

Privileging collaborative authorship among the participants in this study not only reflects the reality of an evolving educational landscape where co-teaching and cooperation is gaining importance, it also highlights a substantial skill that is often overlooked and sometimes (unfortunately) given less credence: multiple authorship. Ede and Lunsford (2001) note that academia often favors "autonomous authorship," over collaborative

authorship. Pre-service teachers of any kind are expected to participate in the creation of collaborative documents including curriculums and master syllabi. The creation of a graphic novelette is a productive exercise in developing interpersonal composition skills that facilitate the understanding of key concepts for pre-service elementary education teachers fostering discursive and professional relationships with fellow educators.

Science Education and Graphic Novels

The creation of the graphic novelettes marks a transition for pre-service elementary teachers from learners to instructors. Developing an engaging yet informative artifact from proverbial "scratch" is a true test of both the pre-service elementary education teachers' base scientific knowledge and their ability to effectively explain complicated scientific principles through a multimodal medium. Tatalovic (2009) states that use of science graphic novels by professionals in scientific fields (including educators) is "to explain science to the public—an audience that is assumed to lack such knowledge" (p. 13). Students come to teachers with a variety of capital including social, cultural, linguistic, and intellectual. It becomes the duty of the teacher to enhance the already admirable intellectual capital the students bring to the class, and graphic novels in the content areas are another means to help explain and study new concepts for students.

Brozo and Mayville (2012) state that as literacies change and media evolves, secondary content teachers are responsible for exploring new and varied alternatives to instruction. One of the teachers Brozo and Mayville studied was a middle school science teacher. The teacher's decision to utilize a graphic novel as the primary text for a unit on chemical reactions reflects an acknowledgement of interdisciplinary education and multimodality. A significant finding in this study is the enthusiasm the middle school students had for the graphic novel with the middle school teacher stating, "I didn't have to ask the students to begin their assigned reading—it just happened" (p. 14). Recognizing this growing trend is something pre-service teachers of all disciplines need to be aware of when going through methods courses and even during student teaching.

One important myth regarding graphic novel usage that needs to be dispelled is the notion that graphic novels and comic books are sophomoric in nature. This cliché has become more conspicuous with the success of popular shows such as *The Big Bang Theory*. The sitcom has a heavy scientific angle with the main characters being professors of science at a local university. However, the emphasis on ridiculing the main characters for their passionate embracing of superhero literature does little to advance the proverbial "cause" of graphic novels and comic books. Interestingly enough, Tatalovic (2009) addresses the very notion of science in superhero narratives. Tatalovic's support of the superhero genre as being a healthy and positive arena in which to entertain discussions of plausible scientific realities (p. 3) presents a growth in the fields of both science education and literacy. In exploring how superhero narratives defy scientific logic and principles, higher orders of thinking ensue including application, evaluation, analysis, and synthesis. As such, regarding the fiction of superhero comics as being a valid artifact for exploring real-world scientific discussions becomes legitimized. This legitimization of accessing superhero literature to spur discussions of scientific principles was also explored in James Kakalios' *The Physics of Superheroes* (2005).

Brozo, Moorman, and Meyer's book *Wham!: Teaching with Graphic Novels Across the Curriculum* (2014) gives instructional strategies for utilizing graphic novels across the disciplines with science receiving a fair amount of attention. This book also reflects much of the current educational discourse on graphic novels and education; the focus is on reading and responding to published works that address a given subject matter. Graphic novels such as *Max Axiom* and *T-Minus* are the mainstays in the burgeoning literature that addresses the use of sequential art in science courses, and this is to be commended and encouraged. The more a student is exposed to diverse forms of media, the more opportunity for a student to utilize his/her "multiliteracies" (The New London Group, 1996). However, there is limited research on students creating scientific graphic novels.

While it is not specifically related to scientific graphic novels, Bitz (2004) studied how the creation of autobiographical comic books by inner city students promoted literacy and encouraged students to take ownership of their work and learning. Bitz goes so far as to say that "...manuscripts and comic books represent more writing than they had produced in English class throughout the entire school year (p. 585)." The creation of original content is essential here, and Bitz's study stands as an example of how students can take information, synthesize it, and apply it in a multimodal fashion.

Purpose of the Study

The purpose of this study was to explore the effects of having pre-service elementary education teachers create original graphic novelettes for use with their future classes. Of particular interest to the researchers was how the pre-service elementary education teachers created their original graphic novelettes and how these same pre-service teachers utilized the medium of sequential art to explain complex scientific concepts to students. This study was approved by the University IRB Committee. The research questions for this study were as follows:

(a) What are the affordances and constraints of having pre-service elementary education teachers utilize and/or create graphic novels in science classrooms?
(b) Does the creation of original graphic novels by pre-service elementary education teachers facilitate the learning of pedagogical skills, content knowledge, both, or neither? Why?
(c) How do pre-service elementary education teachers respond to the usage of graphic novels in science education methods courses?

In other words, did the pre-service elementary education teachers find the usage and/or creation of graphic novels useful?

Methods

Literacy Framework and the Connection to Teacher Preparation

Recognizing the importance of "multiliteracies" (The New London Group, 1996) within the construct of educator preparation is integral to the success of aspiring educators in any discipline. With science education, the ability to not only understand, but also disseminate, complex and vital scientific principles is of profound import. Embracing an understanding of literacy beyond that of simply reading and writing is to invite progress into education, and science education has done this through the advent of STEAM education (Science, Technology, Engineering, Art, and Mechanics). Ntiri (2009) viewed the acquisition of literacy as, "more than to psychologically and mechanically dominate reading and writing techniques" (p. 99).

This trend of recognizing literacy beyond the traditional boundaries is shared by the Next Generation Science Standards (NGSS) which, as was stated earlier, are informed by the Common Core State Standards (CCSS) in both mathematics and language arts. The CCSS Reading Anchor #7, which the NGSS explicitly reference (NGSS Appendix M), asserts that educators should be able to, "Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words" (National Governors Association Center for Best Practices & Council of Chief State School Offers, 2010). Pre-service elementary educators creating and sharing graphic novelettes supports this.

Tatalovich (2009) crystallizes this theoretical framework by stating, "This special genre of education science-themed comics may help to promote and explain science to students and the general public" (p. 4). A recognition and privileging of multiliteracies in science research (Hagood, 2013; Koester, 2015) and education further exemplifies that the creation of graphic novelettes is not only productive for the educators who create them, but those same graphic novelettes have the potential to bridge the proverbial gap between scientists and students/general public. In short, "There is now evidence that educational comics and related single-frame cartoons can be useful for teaching science" (p. 4).

Participants

A total of 39 pre-service elementary education teachers over 3 separate classes participated in this study. All of the classes were elementary science methods courses. 36 of the participants were women, and 3 of the participants were men. All of the participants were then randomly grouped into groups of 3-4 depending on the number of students in each class. There were no exclusion criteria for the participants in this study.

Study Structure

Participants in all three classes were first provided with background information on the structure of graphic novels and how graphic novels are drafted. Of particular emphasis during this review process was how graphic novels are created (McCloud, 2006; O'Neil, 2001). The participants were also provided with the parameters for the project which had the following criteria:

1. Participants were told to pick a scientific principle or topic to create a 2-3 page graphic novelette about. No topics were provided by the researchers
2. Participants were allowed to pick any medium to create the graphic novelette. This medium could be physical or digital.
3. Participants drafted a preliminary graphic novelette in a storyboard style with sketches.
4. Participants presented the graphic novelette to the class and the researchers.

The participants first drafted a script for the graphic novelettes. The general structure of the script is not much different from traditional script writing. The participants then took the script that had been written and applied it to the page with rough pencil sketches, similar to storyboards. Eisner (1985) himself even emphasizes the importance of storyboards in both motion pictures and comics (p. 146). The storyboarding served as a "rough draft" of the graphic novelette, and O'Neil (2001) highlighted the importance of storyboarding when creating comics (p. 30).

Utilizing the storyboards, participants then completed the graphic novelettes and prepared a 10 minute visual presentation for the class to share both the actual graphic novelette as well as their process for creating the graphic novelette. The graphic novelettes were then evaluated for "Use and Accuracy of Science Content" and "Graphic Comic Features."

Data Sources

Qualitative Measures

The study used a modified "cross-case analysis" (Stake, 1995) in order to ascertain an understanding of the affordances and constraints of graphic novelettes created by pre-service elementary education teachers. The data sources for this study included the graphic novelettes themselves, the presentations the participants provided, and a survey completed by the participants.

The graphic novelettes were reviewed using what Stake (1995) terms "Document Review: (p, 68). Additionally, the presentations and surveys were analyzed by three participant observers. All observers used the same scoring rubrics, collected field notes about thoughts that developed through the presentation process and reviewed the novelette.

Findings

Qualitative Findings

All of the evaluations of the graphic novelettes were coded independently by one of the researchers on the project. The coding process used was Bogdan and Biklen (1998) which included both the score average and range on each item on the rubric. The scoring was followed by the addition of written comments about each item by the three observers. These scores and comments were analyzed

for general themes and questions the researchers noted. Then the field notes were reviewed and additional comments were added to each of the categories developed and ultimately named. Finally, the products were examined to provide information used as examples to explain the categories. Once a category was considered "saturated" or fully described and persistent across the data sources the researcher presented the categories and explanations to the other two researchers for assurances of agreement on the saturation of the data, the explanations, and the inclusion as a pattern.

The graphic novelettes created by the pre-service elementary education teachers were evaluated by the researchers focusing on 3 specific categories:

- Learning about science content
- Visualizing content
- Future use of the graphic novelette as a teaching/learning tool

Learning about Science Content

While the ability of the pre-service elementary education teachers to produce multimodal texts for student use was the original intent of this study, the scientific competencies of the participants became a major factor when the data was analyzed. As Tatalovich (2009) had stated, the use of scientific graphic novels and comics has benefits for bridging the gap between scientists (or, in the case of schools, science teachers), and the general public (students). The data collected in this study revealed that some participants had difficulty relaying the details of scientific principles and concepts to general audiences.

Scientific inaccuracies present in the graphic novelettes were most notable in the visuals the students produced. It is also important to note here that the participants were given the freedom to create the graphic novelettes using any technology they wished. This resulted in a mix of graphic novelettes that ranged from hand-drawn, to software aided (Comic Life), to PowerPoint slides that were printed out as pages. Nevertheless, recognizing lapses in scientific competencies was apparent when the art was analyzed.

Of particular note was the graphic novelette titled "Phases of the Moon" which depicted the Sun, the Earth, and the Moon in melodramatic scenes that mimicked a soap opera. At one point, the Moon states, "Finally some time away from that needy Earth. I like being invisible as a **New Moon** once in a while." Accompanying this dialogue is an image of the Earth and the Moon being separated by a large brick wall in space (see Figure 1).

Explaining the concept of a New Moon to an elementary aged student requires the child to synthesize the fact that even though the moon is not visible, it is still present. However, utilizing a brick wall in space to cover up the moon can be literally interpreted; in other words, a young student could read this panel of the graphic novelette and assume that there actually is a large brick wall in space that covers up the moon during a New Moon. This reflects Piaget's theory on the intellectual development of a learner particularly as it relates to the "Concrete-Operational Stage" where children are in the process of developing, "an internal mental activity that enables children to modify and reorganize their images and symbols to reach a logical conclusion" (Shaffer & Kipp, 2010).

Placing an imaginary brick wall in space could be interpreted as being metaphorical; in other words, the author wants to emphasize the fact that the moon cannot be seen during the New Moon phase and the brick wall serves as the physical representation of this abstract concept. What is significant about this image and accompanying story is the lack of explanation of the wall and its purpose in the contextualized universe of the graphic novelette. When taking the actual science of the lunar orbit into account, this wall becomes even more troublesome.

Hodgson and Pyle (2008) have studied assessment in science education. One of the assertions they put forth concerns how drawings can help educators identify student understanding: "Drawings might reveal how a pupil perceives an object or an idea and how perceptions change from pre-assessment through to formative and post-assessment. Hence, these modes [visual] are useful for identifying misconceptions and shifts in thinking" (p. 9). Koester (2015) also advocates for incorporating artistic expression into science education in the efforts of demystifying the sometimes complex nature of science. This researched trend of utilizing art and drawings in science education as a means to assess for understanding informs one of the findings of this study: that the art produced for the graphic novelettes partially indicated the pre-service elementary education teachers' scientific competencies.

There were other examples of scientific inconsistencies as well throughout the study. Another group of students used an image of the planet Venus in a panel about the planet Mercury (see Figure 2).

Another group completed a visually impressive graphic novelette, but the science content was nearly non-existent despite the perameters for the assignment being to present a scientific principle or concept. The story involved the planet Saturn going on a journey to find "his six pillars of character ribbons" (See Figure 3). The value of character education is not in question here as character eduation is a fundamental and integral part of the foundation of a student's overal growth. What is in question here is how character education informs and is informed by the scientific characteristics of the Solar System's second largest planet. Throughout the graphic novelette, there is very little connection to science and instead utilizes the planet Saturn as a character which, aside from the rings, exudes very limited scientifc accuracies.

It must be reitterated here that the students involved in this study were elementary education students and *not* science education students. However, elementary teachers are required to teach certain scientific prinicples and concepts, and that knowledge is measured through the passing of the Praxis Elementary Science Assessment.

The researchers also noted during the presentations that these scientific innacuracies were present. During the scoring of the participants' graphic novelettes, the lowest cumulative score from the

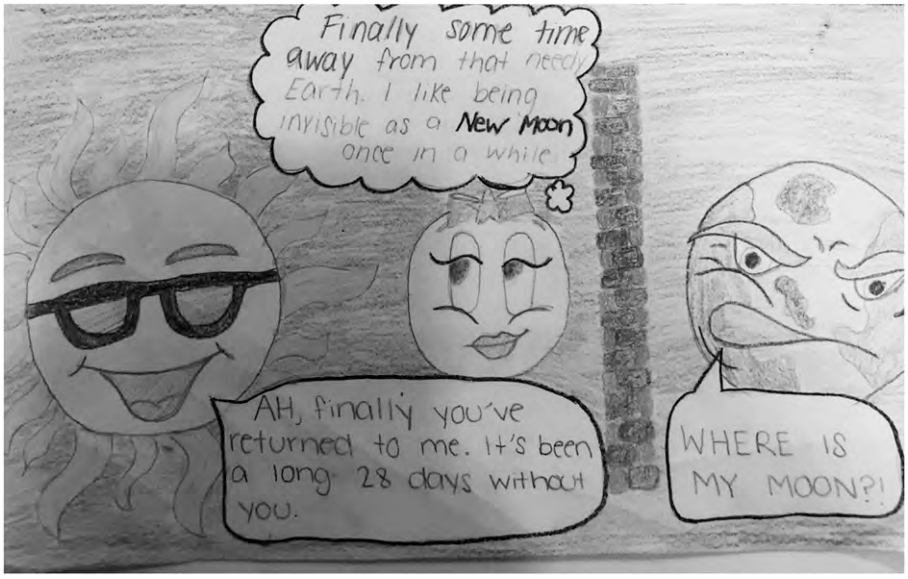

Figure 1. Phases of the moon graphic novelette. This graphic novelette example from a teacher candidate portrays the Sun, the Moon, and the Earth.

researchers were in the areas of "Illustrations are clear and do not cause misconceptions," and "Content standards are clearly identified." Both of these scoring paramters for the project indicate that the scienitific content and the presentation thereof were areas of concern for the researchers.

Visualizing Content

The visualization of the scientific content by the participants was touched upon in the previous section, but the style of that visualization is important as it reveals a great deal about the participants' artistic self-awareness. Requirements for the assignment did not specify a medium or style which the students needed to utilize in order to attain credit for the assignment. Participants were free to pick whichever media they were most comfortable creating with, and this was stressed during the whole group instruction and explanation of the assignment.

Despite the fact that participants were given a choice with which to create content, most groups created the graphic novels using computer software as doing so limited the amount of hand drawn images the participants needed to do. Throughout the study, this became a major factor for both the researchers and the participants to consider as participants frequently expressed doubt in their ability to visually create a scene by hand. In some ways, the participants' apprehension to hand drawing the graphic novelettes became a considerable limitation. The media which the students created the graphic novels included Microsoft Word with downloaded images, Comic Life (downloadable software), storyboardthat.com, and even Microsoft PowerPoint.

However, it needs to be stressed that the choice of medium with which to create the content for the assignment and the artwork itself were not factors in determining the grade for this assignment. The input from the researchers reflects this as most of the comments addressed the integration of the images into the graphic novelettes and the clarity of the images as they pertained to the production of the graphic novelettes (how easy the images were to understand through photocopying and displaying on a projector).

As was also stated earlier, the lowest score during the scoring of the participants' graphic novelettes was "Illustrations are clear and do not cause misconceptions." The lack of clarity in the graphic novels was complicated by the scientific

Figure 2. Finding a new "Mercury" Page. The graphic novelette example from a teacher candidate portrays aliens searching for a new home and identifying the planet on the page as "Mercury."

inaccuracies that were also stated earlier. To be clear, the *quality* of the art was not in question here as the researchers were cognizant of the participants' varied artistic abilities; this resulted in many of the participants utilizing the media cited earlier to complete the graphic novelettes. The *clarity* of the art and accompanying text was what the researchers found to be unclear.

Future Use of the Graphic Novelette as a Teaching/Learning Tool

Gauging the use of graphic novelettes as a teaching tool for the pre-service elementary education teachers beyond this class was really about gauging a response of the participants' enthusiasm for the project. Much of the research on graphic novels reflect a positive experience on the part of the participants or students (Bitz, 2004; Cary, 2004; Frey & Fisher, 2004; Wolk, 2007). This study also reflects this trend with the vast majority of the participants citing that they

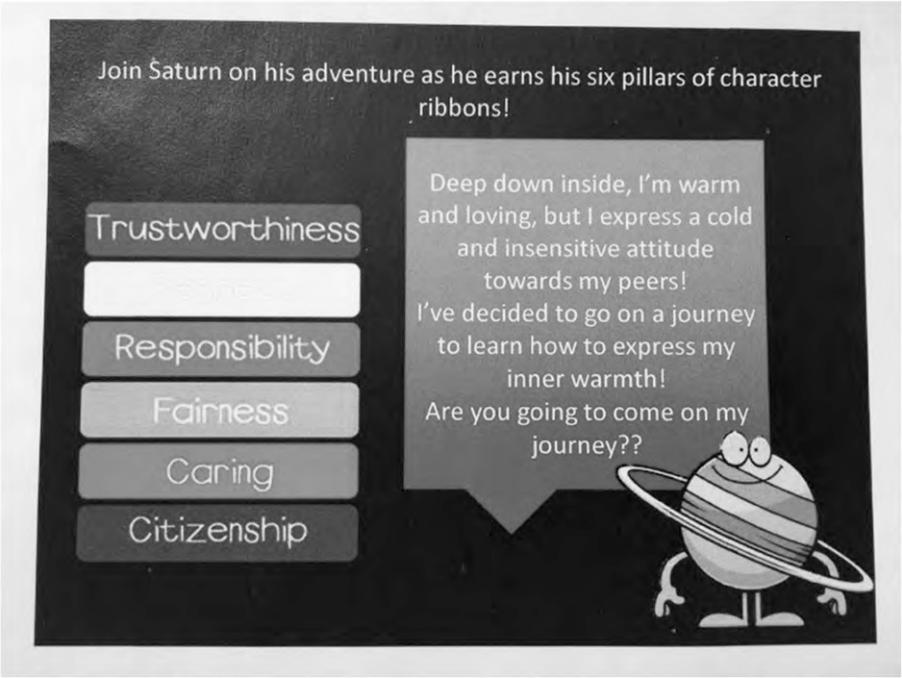

Figure 3. Saturn character education page. The graphic novelette example from a teacher candidate shows the planet Saturn earning character education ribbons.

were "Most Agreeable" with the notion of utilizing the graphic novelette in their own classes.

The vast majority of the participants left the course with a graphic novelette that could be used in a future classroom and noted that they enjoyed the process. While the enthusiasm the participants displayed and cited reflects well on the process of creating the graphic novelettes, that enthusiasm and stated future use of self-produced scientific content includes the scientifically inaccurate graphic novelettes that were disseminated earlier in this piece. The procedures for this research did not include a scientific accuracy component, and that is something that will be discussed in the future studies section. The only informal scientific accuracy checks that occurred throughout the process were during the presentations with some of the researchers asking questions regarding the images and content of the graphic novelettes.

The enthusiasm for the project reflects well on the idea of using the graphic novelettes in the classroom, but it is also dissonant with the self-professed anxiety among the participants that they would need to use their artistic skills to complete the project. This is not necessarily an indication that the enthusiasm for the project is an exclusive result of being a participant in the study; what it does indicate is an understanding among the participants that multimodal projects have benefits for both students and teachers.

Implications

Looking back at the data collected and analyzed, the major implication for this study is how science content was interspersed with the methods in this course. When the graphic novelettes were completed and presented, the abundance of incorrect science information led the researchers to reconsider the symbiotic relationship between science education methods and science content.

This study has implications for science methods professors who recognize gaps in science knowledge among teacher candidates. The nature of this implication is not to denounce the talented and knowledgeable teacher candidates who participated in this study: far from it. Instead, this major implication is to highlight a concern among methods professors of all disciplines and at every level of teacher preparation. Teacher candidates come to methods courses with their intellectual capital being the foundation of their growth while learning pedagogical skills that will aid them in their work as teachers. This study has helped shed light on how content knowledge is sometimes taken for granted by both the teacher candidates *and* the professors of methods courses.

Another implication for this study was the impact of artistic ability on the production of the graphic novels. As was mentioned in the data analysis section, the participants in this study opted for artistic methods which required little to no hand-drawing of pictures while consistently citing their self-proclaimed lack of artistic ability as the reason. For elementary education teacher candidates, this was an interesting finding as much of the elementary classroom is multimodal in nature. Elementary classrooms are very visually designed with students being provided multiple modes of communication to share ideas and create. However, this could also reflect a shift in preferred medium for both teacher candidates and classroom students. Focusing on creating visuals through technology is also part of next generation standards, and the comfort level that the participants showed with technology is an indication that the next generation standards are accurate in their scope.

The array of literacies needed by a science educator is profound, and the creation of graphic novelettes may be one of the creativity literacies future educators need to be familiar with. Presenting scientific concepts in visual formats may be helpful to diverse learners and touch upon the unique multiliteracies of various learners.

Future Studies

Looking forward, the researchers see a lot of potential in continuing to expand the scope of this study. The findings and, more importantly, the questions that arose throughout data collection and analysis will inform future studies.

For future studies, an emphasis needs to be placed upon the content knowledge of teacher candidates and how teacher candidates' intellectual capital influences the creation of graphic novelettes. Given the findings of this study, the researchers saw a need to measure whether the creation of the graphic novelettes can be used as an indicator of understanding among the teacher candidates. Specifically, a future study where the teacher candidates are taught a particular concept (gravity, water cycle, cloud formation, etc.) would be taught to the teacher candidates with the teacher candidates then creating a graphic novelette on that particular concept. This is directly opposite what was done in this study as participants were asked to create a graphic novelette about a concept of their choosing.

Additionally, the scope of this study can be expanded beyond science education. While this study was specifically focused on science education, the findings indicated issues that may be applicable to other areas of teacher preparation. If teacher candidates had difficulty with content in science education, the question of whether or not that trend was consistent across various disciplines became a significant concern among the researchers. This study could be replicated across various disciplines to determine whether or not content knowledge is an issue for other teacher preparation areas. The importance of this in elementary teacher education is particularly important as teacher candidates are required to balance content knowledge from multiple disciplines.

Concluding Discussion

This study looked to explore the affordances and constraints of pre service elementary teachers creating science graphic novelettes for use in their future classrooms. All of the participants were asked to select a scientific principle and create the graphic novelette utilizing any artistic method(s) they felt most comfortable using. After creating the graphic novelettes in groups of 3-4, the novelettes were presented in class to both the researchers and fellow classmates.

The major finding from this study was the inconsistency of scientific content knowledge among the participants which manifested in the creation and presentation of the graphic novelettes. There were multiple instances of the participants creating graphic novelettes with either incorrect or confusing scientific information. However, this finding does not necessarily reflect the content knowledge skillset of the participants. Rather, it served as an indication of how content and methods are bridged during courses which are focused on pedagogical strategies. In other words, linking content to methods sometimes results in confusion. Even though Tatalovic's support of graphic novels and comic books in science classrooms is rooted in the ability of the comic medium, "to explain science to the public" (2009, p. 13), the results from this study highlight the complicated relationship between scientific content and the teaching of said content.

Brozo and Mayville (2012) recognized the relationship between content and graphic novels in their study on utilizing graphic novels in secondary education highlighting the benefits of the medium in comparison to other media:

> Supporting secondary teachers in this kind of reform practice that offers responsive disciplinary literacy to a range of learners within the everyday flow of instruction may have as much potential to bring about higher student achievement and less resistance as other far more costly and disruptive initiatives (p. 17).

Graphic novels can serve as a means of exploring concepts in science while privileging "multiliteracies" (New London Group, 1996). While the some of the content created by the participants in this study was not always accurate, the creative skillsets displayed support Bitz's (2004) findings from his study with urban youth, mainly that participants were able to create original content through a multimodal medium.

The artistic methods of the participants in this study was also a major finding. Participants consistently rated their own artistic abilities poorly, and the media utilized for the graphic novelettes reflected that trend. Most of the students used digital media to complete their graphic novelettes. While graphic novels and sequential art are traditionally hand drawn, the participants' decisions to primarily use digital media reflected a shift in which type of media most students are comfortable with.

This study showed both affordances and constraints in regards to having teacher candidates create graphic novelettes in science education. While the participants' enthusiasm was positive in response to creating the graphic novelettes, their self-professed artistic insecurity resulted in mostly digital graphic novelettes. The incorrect scientific content that was displayed was a major cause for concern among the researchers, but it reflected a more general matter: that being the link between content courses and methods courses during teacher preparation. Looking forward, future studies should look to expand the scope of this study beyond elementary science education and into other disciplines.

References

Bitz, M. (2004). The comic book project: Forging alternative pathways to literacy. *Journal of Adolescent & Adult Literacy, 47*(7), 574-586.

Bogdan, R., & Biklen, S.K. (1998). *Qualitative research for education: An introduction to theory and methods*. Boston, MA: Allyn and Bacon.

Brozo, W.G., & Mayville, M. (2012). Reforming secondary disciplinary instruction with graphic novels. *New England Reading Association Journal, 48*(1), 11-20.

Brozo, W.G., Moorman, G., & Meyer, C.K. (2014). *Wham! Teaching with graphic novels across the curriculum*. New York, NY: Teachers College Press.

Carter, J. B. (Ed.). (2007). *Building literacy connections with graphic novels: Page by page, panel by panel*. Urbana, IL: National Council of Teachers of English.

Cary, S. (2004). *Going graphic: Comics at work in the multilingual classroom*. Portsmouth, NH: Heinemann.

Christensen, L. L. (2006). Graphic global conflict: Graphic novels in the high

school social studies classroom. *Social Studies, 97*(6), 227-230.

Eckard, S. (Ed.). (2015). *Yin and yang in the English classroom: Teaching with popular culture texts*. Lanham, MD: Rowman & Littlefield.

Ede, L., & Lunsford, A.A. (2001). Collaboration and concepts of authorship. *PMLA, 116*(2), 354-369.

Eisner, W. (1985). *Comics & Sequential Art: Principles & Practice of the World's Most Popular Art Form*. Tamarac, FL: Poorhouse Press.

Frey, N., & Fisher, D. (2004). Using graphic novels, Anime, and the internet in an urban high school. *The English Journal, 93*(3), 19-25.

Hagood, M. (2013). Lessons learned from Amanda Baggs: Implications for new media literacies education. In B. De Abreu & P. Mihailidis (Eds.), *Media literacy education in action: Theoretical and pedagogical perspectives* (pp. 37-44). New York, NY: Routledge.

Hodgson, C., & Pyle, K. (2008). *A literature review of assessment for learning in science*. National Foundation for Educational Research.

Jee, B.D., & Anggoro, F.K. (2012). Comic cognition: Exploring the potential impacts of science comics.

Journal of Cognitive Education and Psychology, 11(2), 196-208.

Kakalios, J. (2005). *The physics of superheroes*. New York, NY: Gotham Books.

Koester, M. (2015). *Science teachers who draw: The red is always there*. Blue Mounds, WI: Deep University Press.

McCloud, S. (2006). *Making comics: Storytelling secrets of comics, manga and graphic novels.* New York, NY: Harper Collins.

Morice, D. (2002). *Poetry Comics: An animated anthology*. New York, NY: T&W Books.

National Governors Association Center for Best Practices & Council of Chief State School Officers.

(2010). *Common core state standards for English language arts and literacy in history/social studies, science, and technical subjects.* Washington, DC: Authors.

The New London Group. (1996). A pedagogy of multiliteracies: Designing social futures. *Harvard Educational Review, 66*(1), 60-92.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.

Ntiri, D. W. (2009). Toward a functional and culturally salient definition of literacy. *Adult Basic Education & Literacy Journal, 3*(2), 97-104.

O'Neil, D. (2001). *The DC comics guide to writing comics*. New York, NY: DC Comics.

Reilly, E. (2015). Superheroes in math class: Using comics to teach diversity awareness. *Works and Days, 32*, 61-74.

Romagnoli, A., & Pagnucci, G. (2013). *Enter the superheroes: American values, culture, and the canon of superhero literature*. Lanham, MD: Scarecrow.

Schwarz, G. (2006). Expanding literacies through graphic novels. *The English Journal, 95*(6), 58-64.

Shaffer, D. R., & Kipp, K. (2010). *Developmental Psychology Childhood and Adolescence*. Belmont, CA: Wadsworth Publishing.

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: Sage.

Tatalovic, M. (2009). Science comics as tools for science education and communication: a brief, exploratory study. *JCOM: Journal of Science Communication, 8*(4), 1-17.

Wolk, D. (2007). *Reading comics: How graphic novels work and what they mean*. Boston, MA: Da Capo Press.

Dr. Alex Romagnoli (aromagno@monmouth.edu) Monmouth University

Dr. Judith Bazler (jbazler@monmouth.edu) Monmouth University

Dr. Meta Van Sickle (vansicklem@cofc.edu) College of Charleston