AC 2010-1639: USING GRAPHIC NOVELS TO COMMUNICATE ENGINEERING EXPERIENCES IN AN URBAN MIDDLE SCHOOL

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Using Graphic Novels to Communicate Engineering Experiences in an Urban Middle School

Abstract: Graphic novels are a rich visual medium through which reluctant or struggling writers can communicate their understanding of scientific/engineering content in a creative personal narrative. As part of a National Science Foundation sponsored program, an engineering graduate student was paired with an urban middle school teacher to develop and implement engineering and science-based modules to enhance the curriculum. In this activity, students were asked to create graphic novels based on their experiences in these modules, science fair activities, or a topic in the science curriculum they found fascinating. The middle school participants were 6th, 7th and 8th grade students from groups traditionally underrepresented in science and technology fields. Seventy percent of the participants qualified for Title I remediation and the school ranked in the top 12% of the bottom tier in the district-wide standardized test. The poor scores were attributed to the students’ inability to decode the test questions and lack of context in the existing science curriculum.

Integrating language and graphic arts into the science curriculum is critical to helping the students learn how to effectively organize, synthesize, and communicate knowledge. In our case, the act of organizing a story with a beginning, middle, and an end helped students put their experiences in science/engineering activities in proper context. It also provided a medium for the students to express their thoughts, excitement, and discoveries via a less formal document. The illustrations in the novels allowed the students to capture the details of what they had observed during an activity even though they may not have the vocabulary to describe what they experienced. Subsequent editing of the sketches for inclusion in the novel provided an opportunity for the students to explore each other’s results and observations. Moreover, since space was limited, they had to defend their decision to include some details while omitting others. The finished novels demonstrated the student’s mastery of the content through accurate visual depictions of the processes used in scientific discovery and innovation. The student authors were invited to read their novels with the students in the lower grades to promote science/engineering literacy throughout the school.

The module described above outlines the process by which students in grades 6, 7, and 8 created graphic novels with science and engineering themes. The lesson plans followed the recommendations outlined on the National Association of Comics Art Educator’s website for the process of making a graphic novel. Pre and post activity assessments were administered to evaluate the student’s attitude towards science and engineering, as well as for evidence of understanding and application of the scientific method.

Introduction: A graphic novel is usually a book length work where the content is targeted towards a teenage or adult audience. In contrast to traditional comic strips, the stories in graphic novels are complex and have lengthy storylines. For example, Maus¹, notable for being the first graphic novel to win a Pulitzer Prize, recounts the story of a holocaust survivor in Nazi Germany. There is no consensus regarding the definition of a graphic novel but for the purposes of this activity we considered a graphic novel to be an
illustrated work that involved a complex plot line with a definite beginning middle and end.\(^2\) Introduction of the graphic novel into the classroom and libraries are gaining momentum, in fact coming off a year of poor or flat sales, Capstone publishing house reported an increase in non-fiction graphic novels. This line features the Max Axiom, Super Scientist series.\(^3\) Graphic novels are particularly suitable for struggling readers because much of the decoding of the story occurs in the pictures helping to put the words into context.\(^4\)

Conversely, writing graphic novels opens a universe of expression when dealing with reluctant writers and readers. Graphic novels are a meeting place for words and images. Elements of a good story are dialog, conflict and resolution and writing about what you know. Organization, research and persistence is all you need to write a graphic novel.\(^5\) Kind et al. draws a connection between the creativity that occurs in the production of art works and science/engineering works.\(^6\) They argue there are natural but often overlooked linkages between the two creativity centers. In essence, by exploring science and engineering in a creative exercise such as poetry or story writing encourages students to risk failure, take leaps of faith, and trust in a more creative approach when the outcome is not certain. All of these traits are present in successful engineering and scientific activities and practitioners, but are rarely present or taught in the classroom.

Authentic assessments are designed to be practical, realistic and challenging. They access the higher modes of learning including application of knowledge, analysis, and synthesis.\(^7\) Within the context of surveying middle school students’ attitudes towards science and engineering, understanding of the physical processes and concepts presented in the laboratory, use of the scientific method and dealing with uncertainty, traditional interest inventories and pen and paper exams do not adequately capture a student’s internal narrative. In fact some questions illicit responses that are programmed instead of what the student actually believes. Creating a vehicle for students to express their own opinions and beliefs through creative exercise, reveals their understanding of the material and attitudes towards science and engineering through the choice of subject and plot.

Our research question is: Can graphic novel writing be used as an authentic assessment tool to explore the breadth and context of novice science/engineering student’s knowledge of and attitude towards science and engineering through the use of pictures and words? Specifically can the students combine the information they have learned into a coherent story, include technical vocabulary, imagine how the process they are describing would progress and demonstrate application of the scientific method in the resolution of the story? Additionally what conclusions can be drawn from their choice of subject, characters, plot, conflict and resolution and point of view in the context of attitudes towards engineering and science as a profession?

**Methods:** The middle school participants were 6\(^{th}\), 7\(^{th}\) and 8\(^{th}\) grade students from groups traditionally underrepresented in science and technology fields. Seventy percent of the participants qualified for Title I remediation and the school ranked in the top 12% of the bottom tier in the district-wide standardized test. The current 7\(^{th}\) and 8\(^{th}\) grade classes have had a NSF GK-12 fellow in the science class for 13 months. The 5\(^{th}\) and 6\(^{th}\) grade classes have only had 3 months of dedicated science class with the GK-12 fellow and this is their first long term project in science. To date the 6\(^{th}\), 7\(^{th}\) and 8\(^{th}\) grade classes
have completed their graphic novel. The completion percentages per class are tabulated in table 1.

As an introductory exercise the students in each class were given a science themed graphic novel, Earth-Shaking Facts About Earthquakes with Max Axiom, Super Scientist, to read and discuss before the Graphic Novel activity was assigned. The same rubric was used for each class and they were told they would receive a grade not only for science class but also language arts. (Appendix 1) The project was divided into four steps with a deliverable due at the end of each step. This provided the needed organizational scaffolds for the students and the opportunity for the students to revise their work before continuing to the next part of the project. The first deliverable was a set of index cards containing their chosen topic, character descriptions, ten topic related vocabulary words and definitions to be included in their story, ten facts about their topic, and a brief outline including the central conflict and resolution of their story. (Appendix 2) The second deliverable was a timeline for their story. The timeline served as a guide for the third deliverable which was the graphic organizer/story board for the final graphic novel. This was by far the most difficult part of the project. The graphic organizer (Appendix 3) detailed each scene they had to draw. They had to identify the central theme of the scene and all the elements that would be represented in the scene as well as the dialog. They could either write a list of elements or sketch the scene. Most students chose to write a list but a few made sketches. Each set of blocks on the graphic organizer represented one complete panel for the novel. Most students ended up with between 20-30 panels in their final novel.

A post activity writing reflection was used to assess the student’s opinion of the graphic novel activity, attitudes towards science/engineering and what they thought they learned from the activity. The rubric used to analyze the writing reflection (Appendix 4) and the students’ self-assessment is compared to the assessment of the final product.

**Results:** Initially all four grades were assigned the project but the 5th grade class was not able to complete the assignment in time for inclusion in the results. However compliance was 83% for the rest of the population. Table 1 summarizes the total and class project completion percentages.

Table 1

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of Students</th>
<th>Number of Completed Novels</th>
<th>Percent completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>6th grade</td>
<td>17</td>
<td>12</td>
<td>71%</td>
</tr>
<tr>
<td>7th grade</td>
<td>16</td>
<td>15</td>
<td>94%</td>
</tr>
<tr>
<td>8th grade</td>
<td>21</td>
<td>18</td>
<td>86%</td>
</tr>
<tr>
<td>Total</td>
<td>54</td>
<td>45</td>
<td>83%</td>
</tr>
</tbody>
</table>

Furthermore the students were encouraged to select topics they found fascinating and were familiar with, which explains the frequency of volcanoes and earthquakes as central science themes. This middle school’s science curriculum features earth science, life science and astronomy prominently and the diversity of topics displayed in the 8th grade class reflects the breadth of subjects they have studied. The distribution of science topics in the graphic novels is summarized in Table 2.
Table 2

<table>
<thead>
<tr>
<th>Science Theme</th>
<th>6th grade Novels</th>
<th>7th grade Novels</th>
<th>8th grade Novels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Astronomy</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Volcanoes</td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Earthquakes</td>
<td>4</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Minerals</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Cell theory</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Disease</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Science Fair</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Along with the science or engineering topic, the students were asked to incorporate ten facts and vocabulary into their story. By far this was the most difficult aspect of the project only 31% of the graphic novels had vocabulary words or facts in the story, whereas 100% of the students turned in ten vocabulary words and facts about their topics.

The post activity writing reflection assessed the students’ self-reported ability to make the connection between the scaffolds, the scientific/engineering concepts and the story as well as the attitudes towards STEM and self-expression. Additionally, the students were asked whether they liked the graphic novel activity and why. Each of the students’ responses were coded according to the rubric in Appendix 4. Overall the students did not see a connection between the scaffolds (vocabulary words, facts, story outline, graphic organizers) and the final novel. Figure 1 illustrates the responses the students gave when asked what they learned from the process of writing the graphic novel broken down by grade.

Interestingly, the 7th grade class reported the highest percentage of making the connection but the final novels had the lowest compliance at 28% of including facts and vocabulary in their story. In fact this class had the highest incompletion rate due to not turning in their topic cards, outline and storyboards. Moreover when the students were asked what they learned...
while doing the graphic novel 20% reported learning how to draw, 11% reported learning how to organize a story, the remaining 69% reported learning about their topic. The students in general they did not express an attitude towards science or engineering as shown in figure 2.

Figure 2. Percentages of student that reported an attitude towards science and engineering in their reflective writing activity.

However the students did like the freedom to express themselves although occasionally found it difficult in the context science based story line. Based on the final novels the students were very creative but favored creativity over the central point of the novel, which was to inform the reader about the science or engineering.

Figure 3. Results from the post activity writing reflection regarding the students’ attitudes towards creative expression in the graphic novel activity.
Overall the students reported a positive attitude towards the graphic novel assessment. An equal number of students cited the difficulty of the project as the reason they liked the assessment (22%) and did not like the project (22%). The other reasons cited for liking the project were they enjoyed story telling and drawing. Additionally students reported disliking the project because they did not like doing the research and drawing.

Figure 4 Students’ overall opinion of the Graphic Novel activity.

**Discussion:** Can graphic novel writing be used as an authentic assessment tool to explore the breath and context of novice science/engineering student’s knowledge of and attitude towards science and engineering through the use of pictures and words? Specifically can the students combine the information they have learned into a coherent story, include technical vocabulary, imagine how the process they are describing would progress and demonstrate application of the scientific method in the resolution of the story? The panels shown in figure 5 are taken from a novel written by a 7th grader, she used a real place in her fictional account of The Amazing Adventures of Vinko the Volcano Man. She accurately places Hawaii in the Pacific ring of fire and identifies the source of volcanism in Hawaii is a hot spot. Interestingly, she also expressed the time it takes for the forces in a volcano to build up causing an eruption. Most of the students that wrote about volcanoes attributed the volcanic activity to super powered beings. Another aspect of the integration of science and technology into the story was the presence or absence of the design process and use of the scientific method. As was seen in the panels in figure 5, the scientist is using a computer to analyze data and make a prediction. She is using a computer to do the analysis but the connection to the data collection is not explicitly shown. However she does support her prediction with information that was discussed in class but the scientific method is not completely illustrated. In fact, none of the novels explained the entire process of design or all of the steps in the scientific method.

The students in general had a difficult time integrating the facts and vocabulary with the story. Most were able to envision a volcano erupting, and earthquake, or progression of a disease but could not assign the correct vocabulary to describe what was
happening. They also had difficulty expressing visually or through dialog how the scientists/engineers used the scientific method or design cycle in their professional capacity. This difficulty is also reflected in their standardized testing. In essence this assessment was an accurate reflection of their understanding and difficulty internalizing the process of the scientific method.

Figure 5. These illustrations are taken from an 7th grader’s novel about a volcanic eruption in Hawaii. She depicted the Volcanologist predicting the eruption many years before the eruption based on the location of the volcano in the ring of fire and the presence of the hot spot.

There are indications that some of the laboratory work is making an impression on the students. The panels in figure 6 are taken from an 8th grade novel and these images are the most detailed account of the work of scientists and engineers. The opening scenes take place in a geology research lab where the professor and his students are identifying mineral samples. Notice the streak plates and tools on the desks. This student participated in a mineral lab last year and was able to include the details from that activity in his illustrations. Later in the novel the professor and his students visit a volcanologist who has designed and built a drill used to travel into a volcano. (Figure 7) Neither the features of the drill or the design of the drill are not discussed. The introduction of technology without addressing the engineering that went into the device is a common theme. Generally, the props used in a scene to indicate that a character is engaged in scientific or engineering activity were computers, books, lab coat and beakers.
What conclusions can be drawn from their choice of subject, characters, plot, conflict and resolution and point of view in the context of attitudes towards engineering and science as a profession? Attitudes expressed towards science and engineering and their practitioners were universally positive. Although the connection between the technology present in the stories and the engineers that designed them was not explicit, the practitioners were seen as helpful, resourceful and concerned people. In several stories the geologist/volcanologist tried to get life saving information out to an unaware public at personal cost. For example, the drawings in figure 8, depict a USGS geologist that made an unauthorized statement about an impending earthquake. This breach of protocol cost him his job. Other stories featured medical doctors saving lives, NASA engineers preparing for space flight, geologists, volcanologists and university professors. Frequently the scientists/engineers were endowed with super human attributes such as the ability to fly, move planets, and put villains to sleep. In two stories, there were clearly engineers designing artifacts (drill machine and a robot) an in both cases the engineer was the villain of the piece.
Figure 7. Continuation of the story introduced in figure 2. Here the students and professor are on their trip and meet a rival of Dr. Kamron who has built a manned drill so the geologist’s can explore the volcano. Unfortunately the other professor has evil plans for our hapless explorers. The drill is the reason Dr. Kamron has chosen this volcano but no information is given about why or how the Evil Professor designed and built the drill.

In general the presence of books and computers indicate the student’s view scientists/engineers as educated and actively seeking knowledge as part of their work. Several stories included trips to the library as part of the problem solving strategies, essentially bulking up in knowledge weapons, to prepare for the final conflict with the antagonist in the story. In most stories this conflict was literally a physical fight. Some of the antagonists used their technology to indirectly attack the protagonist as is seen in the story in Figure 7, but all of the main characters fought one another. This may be a result of the language used by the instructors when the “elements of a good story” was taught. The students were asked to build conflict and provide resolution in the story and the prevalence of violence may be a literal interpretation of conflict on the student’s part.

**Conclusion:** Completion of a graphic novel by a student, regardless of the quality of the end product, represented a significant achievement for several reasons. First, it represented a risk on the student’s part because they were asked to reveal their understanding of a science/engineering topic in a medium they do not usually encounter in the classroom. They are accustomed to taking notes, occasionally participating in a laboratory experience and then taking a written test or making a poster. They are comfortable with these forms of assessment, in essence they know what to expect.
Figure 8. These drawings, created by an 8th grader depict a selfless geologist risking his job and friends to warn the public of an impending catastrophic earthquake that only he believes is coming. Of course he was right and in the end he was not able to save the city but there is an epic battle between Mother Nature and her daughter, disguised as the geologist's assistant in these pictures.

There was considerable anxiety surrounding their perception of their own artistic ability and how the quality of their artwork would affect their grade. They did not like that they could be judged on something so subjective. This concern was so persistent that it was the most cited reason for not liking the activity. Additionally, there was no opportunity to cut and paste. By forcing the students to draw original artwork they could not plagiarize or rely on the internet to provide the answer, they had to think for themselves. Finally, the project required mental stamina. The students had to be strategic, make long term plans (they called them pacing charts), and synthesize concepts and tools from disparate subjects to create a cohesive story.

Their stories are varied and exciting; some were able to integrate fact and fiction better than others, but all of the finished novels expressed an interest in science/engineering and viewed the people engaged in scientific activities as caring, passionate, contributing members of society (super powers and all).

Careful planning on the part of the instructor is crucial to the success of this project. It is very easy for both the student and the instructor to lose sight of the purpose of the graphic novel during the development process. The instructor needs to remind the students...
constantly that the purpose of the novel is to inform the reader about the facts and physical processes occurring in the story. Also remind the students to organize the story around the scientific method or the design process. This will help to ensure the content is factual. Timely feedback on the student’s work is necessary especially when working with middle school students since they do not like to “revise” their work at all. For example, one student submitted a completed novel with a storyline that was rejected at the note card milestone and had one-on-one help with the story revision at the graphic organizer milestone, with an addendum correcting the facts in the story but sticking with her original idea. Building time into the project for revision and checking the revisions for accuracy is crucial, otherwise the students will not change their work. Finally, connecting the science/engineering information to the art of story telling through pictures is probably the hardest task for both the students and the instructor. The instructor has to model the process for the students and the students have to do it for themselves.

Graphic Novel writing is an excellent medium to assess novice scientists/engineers understanding of the curriculum content because there is very little they can copy from the internet. Posters, lab reports, writing pieces are frequently exercises in copy/paste activities they require little thought or understanding in the digital age. Few science themed graphic novels exist, and the students cannot plagiarize a drawing as easily as written document. Forcing the students to synthesize and apply the science/engineering content they have learned in to an original story through pictures also encourages the students to organize their thought, think logically and describe their scenes more visually. Hopefully the skills and tools the students learned in the process of writing their novel will be applied to all their work.

References
5. Crilley, Mark., “Getting Students to Write Using Comics.” Teacher Librarian, Vol. 37, Iss.1, 2009
Appendix 1: Graphic Novel Rubric

1. Pick a topic:

2. Research your topic
   a. Create reference cards
   b. 10 facts that must be included in your story

3. Outline the plot of your story

4. Story board the scenes

5. Finished panels
   a. 8x11 white (computer paper) for each scene
   b. Scenes must be drawn and colored (paint, crayon, colored pencils)
   c. Words must be black and inked (using a pen)
   d. Book cover and title

6. Book assembly in class

Grading: Topic Research 20%
         Outline 20%
         Story Board 20%
         Panels 40%

<table>
<thead>
<tr>
<th>Assignment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic Research</td>
<td>Student included some information but references were not in the correct format and student did not include all ten facts</td>
<td>Student found 10 facts and wrote references but format was incorrect</td>
<td>Student research 10 facts and correctly referenced the sources.</td>
<td>Student found 10 facts and used print, internet and video media as sources.</td>
</tr>
<tr>
<td>Outline</td>
<td>Student submitted an outline but the story did not have a beginning middle and end. Outline format was not correct. Bullet point statements of topic sentence, body, conclusion.</td>
<td>Student submitted an outline of a story that had a beginning middle and end but not formatted correctly. Bullet point statements of topic sentence, body, conclusion.</td>
<td>Student submitted an outline of a story that had a beginning middle and end and formatted correctly. Bullet point statements of topic sentence, body, conclusion.</td>
<td>Student submitted an outline of a story that had a beginning middle and end and formatted correctly. Bullet point statements of topic sentence, body, conveying imagery of the story.</td>
</tr>
<tr>
<td>Story Board</td>
<td>Scenes sketched, but are incomplete and do not describe the story or outline.</td>
<td>Scenes sketched, but do not describe the story or outline.</td>
<td>Scenes sketched describe the story or outline.</td>
<td>Scenes sketched describe the story or outline. Imagery is compelling and tells the story.</td>
</tr>
<tr>
<td>Panels</td>
<td>Panels are not completely colored, there are misspellings, or incomplete story. No science all fiction.</td>
<td>Panels are colored but there are misspellings. Missing vocabulary words or facts in the story</td>
<td>Panels are colored, story is complete. Work is sloppy. Missing information</td>
<td>Beautifully colored (illustrated) story, all scientific words are spelled correctly.</td>
</tr>
</tbody>
</table>
Appendix 2

**Format for Graphic Novel**

* Reference Cards (Index Cards) 10 minimum

**Detail**
- Front: ______________________
- Back: ______________________
- Words on details: __________
- These facts must pertain to vocabulary words only
- Number each card

* Make a Lens Lu Card (Use a color card - optional)

**Detail**
- Title: ______________
- Genre: ______________
- Publisher: ____________
- Type Writer: __________
- NAME: ______________

* Character Cards (None only on this card)

**Detail**
- Characters - Protagonist
  - Main Character
  - Supporting Character
  - Name only
  - List all traits
  - Name: ____________________

**Character Traits**

**Character Name**

**Making the Scene**

**Plot**

Create a conflict/resolution card

**Conflict**

**Resolution**

Create the plot in 3 sections

**Beginning**

**Middle**

**Ending**

- Describe the conflict
- Build the climax

- Describe the solution
- Solve all problems

* Remember write the ending first, middle last, and beginning become

**Story Line - Board**

Use sheets of loose leaf paper to illustrate the rough draft pictures.
Use as many as needed to hand-draw the pictures in each section.
DO NOT DRAW ON THE BACK.

**Beginning**

**Middle**

**End**

Use as many as needed to illustrate each part of the plot.
<table>
<thead>
<tr>
<th>GRAPHIC NOVEL</th>
<th>SCENE ORGANIZER</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the Plot/Scene?</td>
<td>Drawing Elements</td>
</tr>
</tbody>
</table>
| The volcano is starting to *wake up*. | It is a stratovolcano. In the evening, the sun is low. Sandhouses by the beaches. Beaches. Palm trees. | “1962 Kintinque”  
May 02 |
| People thinks it nothing and some try to run away. | | |
| 2. Penny is checking into the hotel. | Laptop, suit, suitcases, helmet, umbrella, camera, tee shirt, | Penny (Hi)  
I have a reservation for Fix it!  
“yes I have your name right?” |
| She brought her work things with her on vacation. | | “thank you” |
Appendix 4

Response Rubric

Objectives:

1. Understanding connection between the scientific content and activity scaffolds and the story.
2. Attitudes displayed towards STEM professionals and careers.
3. Attitudes towards self-expression.

The students were asked to respond to the following prompts:

1. What I learned from doing the graphic novel
2. What I did /did not like about doing the graphic novel

<table>
<thead>
<tr>
<th>Response</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connections</td>
<td>Did not report awareness of the connection between the science concepts and the activities</td>
<td>Reported learning scientific information but did not see the connection to the scaffolds or the final story.</td>
<td>Reported learning scientific concepts and making the connection between the scaffolds</td>
</tr>
<tr>
<td>Attitudes towards STEM</td>
<td>Did not express an opinion about the STEM</td>
<td>Reported unfavorable attitude towards STEM topics</td>
<td>Reported favorable attitudes towards STEM</td>
</tr>
<tr>
<td>Attitudes towards Self Expression</td>
<td>Did not express an opinion about the self expression</td>
<td>Expressed an unfavorable opinion about the self expression</td>
<td>Expressed an favorable opinion about the self expression</td>
</tr>
</tbody>
</table>