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Classroom Experience about Cartooning as Assessment in Pre-service Mathematics Content Course

Hoyun Cho, Ph.D.
Capital University

Carolyn Osborne, Ph.D.
Capital University

Tobie Sanders, Ph.D.
Capital University

ABSTRACT Elementary Education pre-service teachers are noted for disliking and even fearing mathematics, so a teaching strategy that increases their enjoyment of mathematics learning must be a powerful one, indeed. When the same strategy can also support problem posing and assess mathematical knowledge and reasoning, providing an occasional alternative to testing, it becomes something to share with other teachers. In this article, we share our experiences with having students represent their understanding of mathematical concepts through cartooning in a Mathematics Education course for Early Childhood Education pre-service teachers. We believe these strategies will work with much younger students, and we suggest future avenues for refining the technique. Data for this study include the cartoons students produced and their answers to a survey on the process of using cartoons to represent their mathematical understanding.

KEYWORDS *Classroom experience, open-ended assessments, pre-service education, cartooning*

Incorporating the Arts in the Classroom

The arts support the development of creativity (Land, 2013; Maguire et al., 2012), communicative skills (Peppler, 2010), achievement (Catterall, 2012), and motivation (Doyle, 2012) amongst students. The question becomes, how do we do so in a way that both complements and supplements mathematical instruction towards specific curricular goals? Taking time to do a creative project within a mathematics class might increase student motivation, but at a cost to time spent on doing mathematics. Mathematics educators need creative projects that increase motivation and focus on the mathematics-centered goals a teacher has for a particular grade level.

Cartooning in the Math Classroom

Cartooning, a process of conceptualizing, drawing, and writing that results in a work which incorporates image and language, in a mathematics classroom supports artistic creativity and specific mathematical goals. The genre of cartooning allows students to use both visual elements and written language to express their ideas. Additionally, cartooning allows for the expression of what a character is thinking, along with what that character is saying, which is a way to express mathematical reasoning. Dabell, Keogh, and Naylor (2008) use "thought bubbles" to represent what different people might think about a concept and then encourage students to express their own thoughts.

As Cho (2012) points out, cartoons have been seen, in the past, as an "enemy" of education. They have been viewed as a trivial substitute for real reading and real thinking. Because vestiges of these anti-cartooning attitudes seem to remain in school settings, the sanctioning of cartoons within a classroom can be motivating for students; they are being encouraged to do something they rarely experience in other parts of their schooling and what they are doing, when they cartoon, is something they associate with fun that is not approved by school authorities.

Cartoons and comics also frequently incorporate humor, which is another source of student motivation. Strong's (2013) work is a handbook for incorporating humor in the classroom. He states:

> Using a humorous "bit" is a great way to liven up a lesson. By "bit" I mean a self-contained, purposely crafted unit of humor. This can be a funny story, a cartoon, a song, a video clip, anything that has been made and planned in advance…Properly adding humorous bits to your lessons can increase student retention of material, lead to higher student results on tests, and create more student engagement. (p. 6)

Humor helps students get into a positive emotional state, which leads to greater engagement and learning. It also can make particular points memorable.

Cartoons can be used in several ways in teaching mathematics. One is the use of an existing cartoon that has mathematics content in it, such as one published in a newspaper or magazine, as the basis for a lesson. Cho (2012) describes how a math teacher developed a series of activities concerning probability around a Born Loser (Samson, 1986) comic in which the main character considers buying a raffle ticket.

A second way is to use cartoons developed specifically for mathematics classrooms, such as those by Dabell, Keogh, & Naylor (2008). These cartoons depict situations that call for mathematical reasoning and invite students to express their thoughts about the situation. These cartoons are not humor based but they are illustrations of mathematics problems using both words and images. The various young people in the cartoons describe their thinking and the reader is then asked to describe his or her own mathematical reasoning.

A third way is to have students create their own cartoons that reflect their mathematical thinking. This third method allows for more complete personal expression than the first two methods. When students create their own cartoons, they have an opportunity to pose their own problems, which supports mathematical creativity (Silver, 1994; Brown & Walter, 2005). The remainder of this article describes what happened as Early Childhood Education majors were asked to represent their mathematical thinking in the form of cartoons.

Pre-service Teachers, Mathematics, and Cartooning

The university at which the current study takes place offers two mathematics courses for Elementary Education majors, Integrated Mathematics I and Integrated Mathematics II, which are designed to help students develop content and pedagogical content knowledge. While the students may have taken more advanced mathematics classes in high school and college, these mathematics education courses are critical for helping students understand what they will be teaching to young children so they can make multiple, sensible explanations to help their students learn how to reason about mathematical problems.

The subjects described in this study began their university experience under the mandates of the No Child Left Behind (NCLB) act, implemented in 2002, which uses standardized testing as a means of assessing student knowledge. NCLB standardized testing of students also influences how schools are rated and even whether schools can stay open. Teachers feel pressured to ensure students do well on these tests, which leads, ironically, to the problematic practice of teaching to the test.

While students were educated under NCLB, their careers as teachers will begin with the Common Core State Standards, (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) requiring many in this cohort to develop ways of thinking about teaching mathematics that are new to them. One way to do this is for the students to experience reason-centered teaching in their mathematics education classes, which is what the instructor does in Integrated Mathematics I and II.

The Cartooning Assignment

Students in Integrated Mathematics discussed the three ways to use cartoon, then they were asked to create cartoons to express a mathematical concept. They had the choice of working individually or in groups. Since this was the first time asking students to draw cartoon in this class and we wanted to see what they would create, students were able to choose the topic from the chapter

in their textbook titled "Thinking Critically" (Long & Millman, 2012) which discusses problem-solving strategies. Along with creating cartoons, students were also asked to write a paragraph describing their cartoon and its mathematical content. These paragraphs were helpful in understanding what the students were thinking and their intentions as they made their cartoons. Fifteen cartoons were created in a class of 28 students, 27 of whom were involved in creating cartoons. Figures 1 and 2 are examples of students' cartoons.

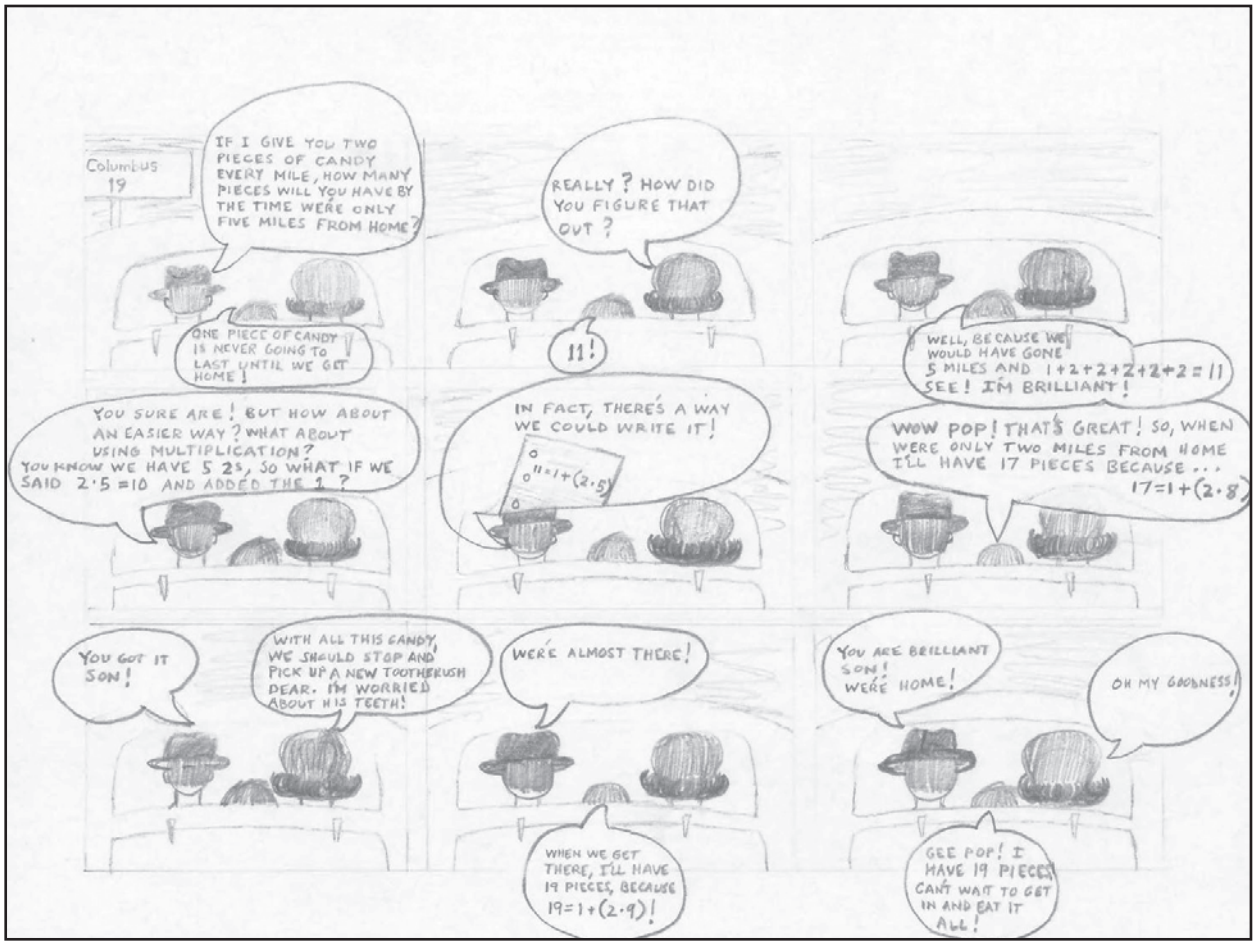

Figure 1. Sample 1 of a student cartoon: Parents scaffold a child's mathematical understanding.

Figure 1 Transcript

Frame 1:

Road sign: Columbus 19

Child: One piece of candy is never going to last until we get home!

Father: If I give you two pieces of candy every mile, how many pieces will you have by the time we're only five miles from home?

Frame 2:

Child: 11!

Mother: Really? How did you figure that out?

Frame 3:

Child: Well, because we would have gone 5 miles and 1 + 2 + 2 + 2 + 2 + 2 = 11. See! I'm brilliant!

Frame 4:

Father: You sure are! But how about an easier way? What about using multiplication? You know we have 5 2s, so what if we said 2 x 5 = 10 and added the 1?

Frame 5:

Father: In fact there's a way we could write it!

[Notebook page with 11 = 1 + (2x5)]

Continued

Figure 1 Transcript *(Continued)*

Frame 6:

Child: Wow Pop! That's great! So, when we're only two miles from home I'll have 17 pieces because…
17 = 1 + (2 x 8)

Frame 7:

Father: You got it son!

Mother: With all this candy, we should stop and pick up a new toothbrush dear. I'm worried about his teeth!

Frame 8:

Father: We're almost there!

Child: When we get there, I'll have 19 pieces because
19 = 1 + (2 x 9)

Frame 9:

Father: You are brilliant son! We're home!

Child: Gee Pop! I have 19 pieces. Can't wait to get in and eat it all!

Mother: Oh my goodness!

The cartoon shown in Figure 1 is an example of a student taking on a huge task: managing a narrative with some humor in it, managing the artistic demands of the cartoon genre with a high level of accuracy, and managing the mathematics. The student, who feels he is not good at mathematics, uses a mathematical concept correctly although two details at the beginning (the road sign and the father's initial statement) set up the problem differently from the way in which it is solved. The road sign should read "Columbus 9" and the father in frame 1 should say "how many pieces will you have by the time we've gone 5 miles."

The cartoon in Figure 1 is an example of authority figures supporting a child's development of mathematical skill. It is also mathematically one of the more sophisticated in the group and the cartoon has appeal because of the student's storytelling and drawing. It also represents a student's choice to stretch his mathematical abilities. These characteristics are all factors that can help a teacher think about students' strengths and challenges and to plan instruction accordingly.

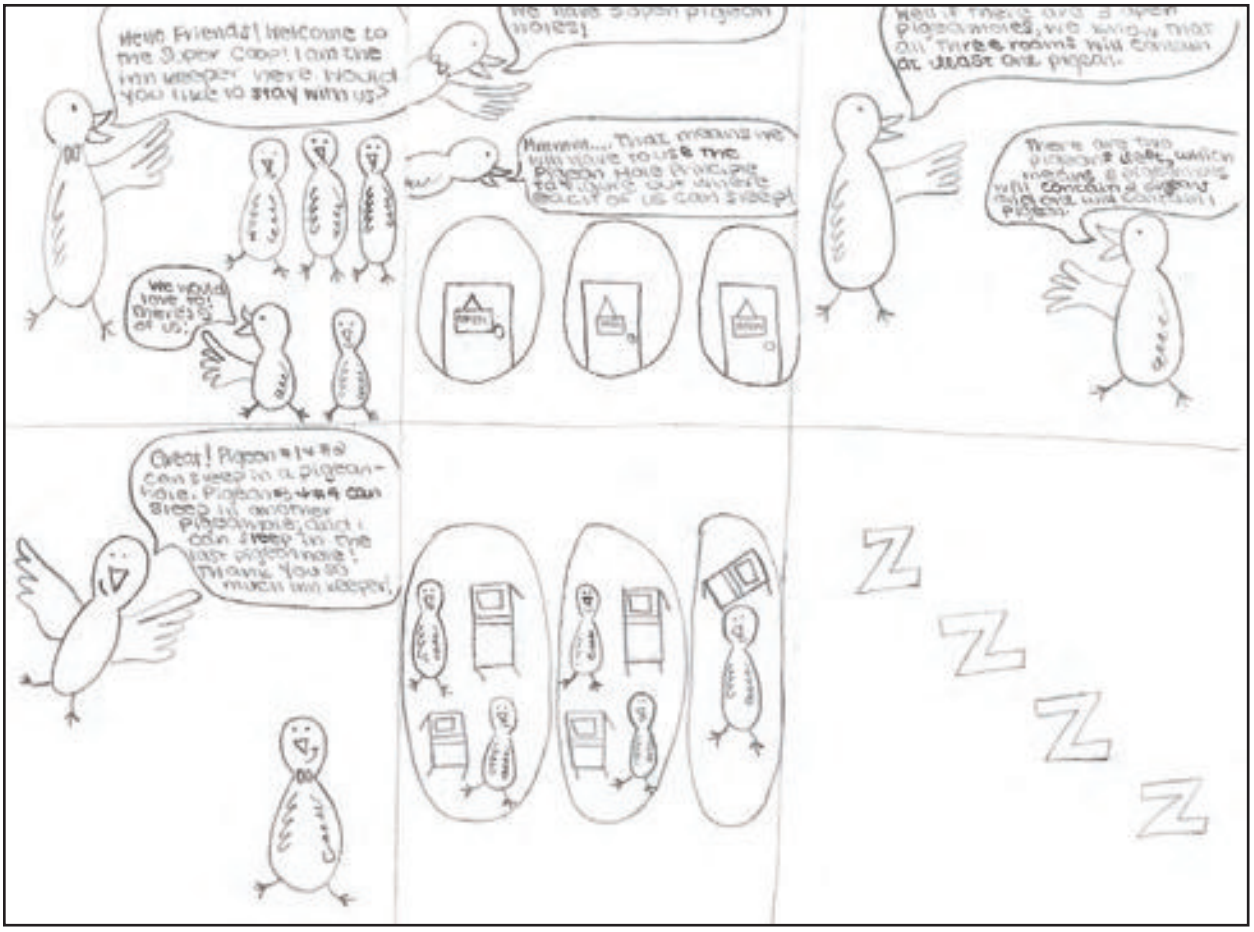

Figure 2. Sample 2 of a student cartoon: The pigeonhole principle illustrated.

Figure 2 Transcript

Frame 1:

Innkeeper: Hello Friends! Welcome to the Super Coop! I am the innkeeper here. Would you like to stay with us?

Visiting pigeon: We would love to! There are 5 of us.

Frame 2:

Innkeeper: We have 3 open pigeonholes!

Visiting pigeon: Hmmm…That means we will have to use the Pigeon Hole Principle to figure out where each of us can sleep!

Frame 2:

Visiting pigeon: Well if there are 3 open pigeonholes, we know that all three rooms will contain at least one pigeon.

Innkeeper: There are two pigeons left which means 2 pigeonholes will contain 2 pigeons and one will contain 1 pigeon.

Frame 2:

Visiting pigeon: Great! Pigeon #1 & #2 can sleep in a pigeonhole. Pigeons #3 & #4 can sleep in another pigeonhole; and I can sleep in the last pigeonhole! Thank you so much innkeeper!

The cartoon shown in Figure 2 is an example of a student representing a concept. While other students used fractions to divide resources among several people or creatures, this student chose to represent the Pigeonhole Principle in both a literal and humorous way. Like the first cartoon, this one reflects a student's handling of both a mathematical concept and the genre of cartooning. This cartoon also represents the fact that this student is comfortable with the concept being represented, although a teacher might wonder if the student could apply the Pigeonhole Principle to situations beyond birds. This would be something to investigate in future instruction.

Students chose a wide range of topics to depict; table 1 shows their range of topics.

Table 1

Students' Cartoon Topics

Mathematical Topic	Number of Cartoons
Patterns	5
Dividing resources among characters	4
Multiplication	2
Shapes	1
Guessing a number	1
Algebra	1
Polya's Problem Solving Process	1

Outside of mathematical content, the first salient feature of the fifteen cartoons that students produced was the relationships presented between the characters in Table 2.

Table 2

Relationships Presented Between the Characters

Relationship	Number
Peer to peer	7
Parent and child	4
Teacher to classroom	3
Individual	1

The choice of characters in the cartoons not only brings a real-world application of mathematics concepts; these choices also reflect aspects of these students' ideas about how mathematics interactions take place among people. Approximately half of the cartoons (seven) that have more than one character reflect some kind of authority structure between the characters. The rest reflect a peer-to-peer situation where participants have equal authority. In the majority of the cartoons that depict authority structures, the person in authority is scaffolding and/or participating in an exploration designed to augment the young person's understanding of a mathematical concept.

Another aspect to consider is how the students engaged with the genre of cartooning, the features one expects of a cartoon. All the cartoons used images and language together to create some kind of narrative structure. Fourteen of the fifteen cartoons used narrative structures to tell a story with a beginning, middle, and end. The other cartoon presented shapes that had human names (as many cartoon characters do) and some relationships between them, but not establishing a storyline. Three cartoons incorporated humor, including one in which a number of pies get divided between some characters that made reference both to Pi Day (March 14) and triangular numbers (on a triangular piece of pie). Humor is not a requirement of a cartoon and is something that requires an extra layer of thought to incorporate in an assignment like this.

Student cartoons present not just mathematical concepts but also pre-service teachers' ability to handle mathematics coupled with a complex narrative genre and their thinking about what it means for human beings to interact around mathematical reasoning, as is seen in the sample cartoons above. These cartoons reflect cooperation and caring as a backdrop to working together to solve problems. As an assessment, then, these

cartoons show us some of the strategies for interpersonal interactions these students know and care enough about to depict. Some anxieties also are apparent in two of the teacher cartoons, which is congruent with what we know about the prevalence of mathematics anxiety among early childhood education majors (Malinsky, Ross, Pannells, & McJunkin, 2006). If we are concerned about the emotional state of students, then cartooning can provide a means to help early childhood education majors overcome some of their math anxiety.

Student Perspectives

In addition to making the cartoons and writing about them, students answered three questions about their perspectives on the whole assignment. The first question had three parts, asking if students enjoyed the assignment and then asking for favorite and least favorite aspects of the assignment. When asked if they enjoyed the process of making the cartoons, students overwhelmingly indicated that they did. Among the 27 students were 34 statements regarding this question, all of which included some form of enjoyment. The two statements that included some negative ideas in relation to enjoyment had to do with students feeling they were not creative or good at drawing. The following chart in Figure 3 shows why students expressed enjoyment of the activity.

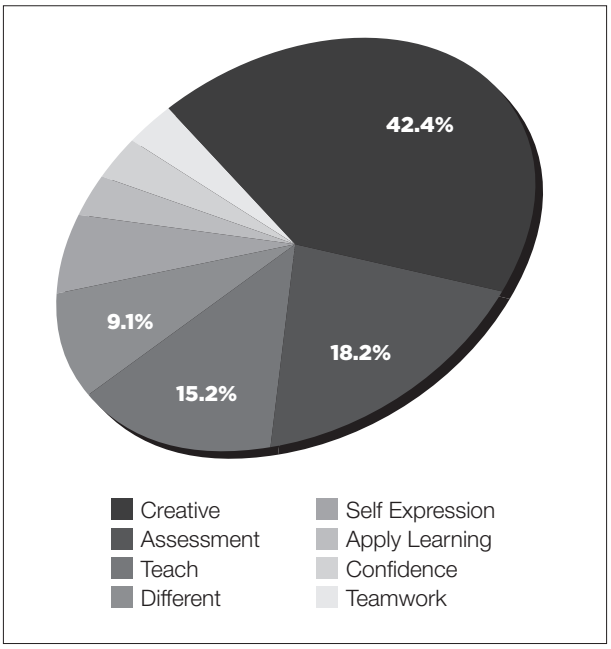

Figure 3. Reasons for enjoyment.

By far, the students liked the opportunity to be creative, although, as we have seen, two statements reflected some concern about not being creative enough. Other interesting responses include recognition that cartooning was a positive alternative to testing as an assessment and also an appreciation for learning a procedure that they could themselves use in the classroom.

When students were asked about their favorite part, they indicated that they enjoyed developing aspects of narrative the most and actually drawing and coloring their creations the most. However, only 7.4% of the students report that the mathematics is their favorite part in Figure 4.

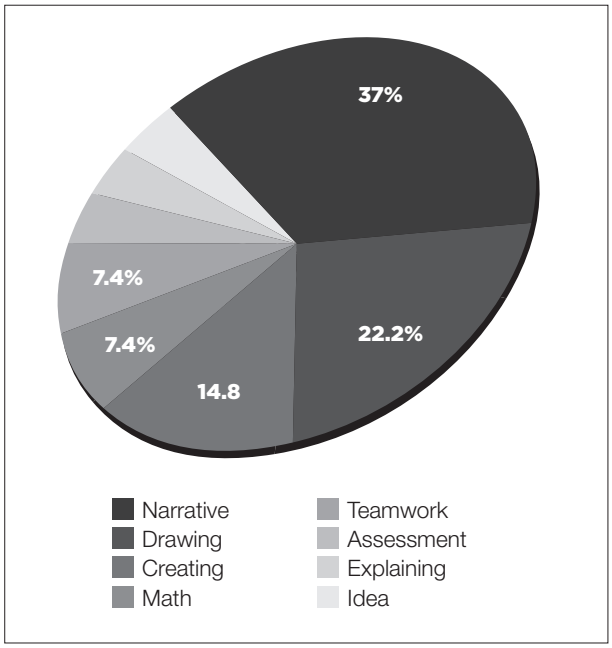

Figure 4. Favorite part.

Additionally, students reiterated their enjoyment of creating the cartoon without being specific about which aspect they liked the best. The emphasis on narrative, drawing, and creativity is an interesting finding in the context of problem posing. Traditional word problems have been criticized (e.g., Greer, 1997, who states that students too often apply mathematical procedures to school-based word problems without thinking them through from a real world perspective) and adjusted (e.g., Bates and Wiest, 2004, who find that students' achievement on word problems improves when the problems are rewritten with references to real things and people in students' lives). Further, Brown and Walter (2005) point out that students may perceive word problems as coming only from teachers or textbooks.

Problem posing through cartooning allows students to take a different kind of authority over their mathematical thinking, through being the source of a problem rather than just the recipient.

Another question asked students specifically about what they enjoyed the least and, ironically, drawing was first on the list in Figure 5.

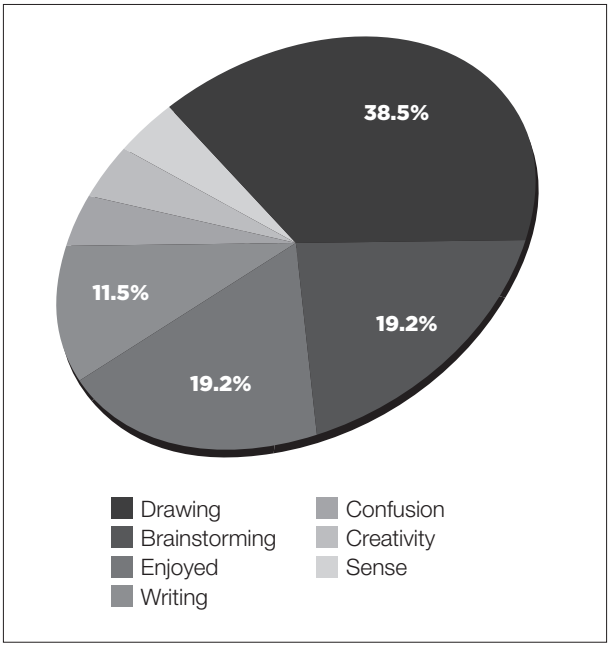

Figure 5. Least favorite aspects.

Some students expressed concern about their inability to draw something that was satisfactory in their minds. One group opted to print out cartoon figures from the internet to get around this problem. Another student created blob-like aliens to express her narrative which got around the drawing issue. Apparently there is not a lot of neutrality about drawing in this group—students either enjoyed it greatly or not at all. One has to wonder whether this concern is specific to college-age students since, in our experience, children tend to be less concerned with the precision of their drawings. Also interesting is the fact that even though students were encouraged by the question to share something they didn't like, five comments indicated that the whole assignment was enjoyable.

The second question of the survey/questionnaire asked students if they thought that the mathematics represented in their comics were correct. They all did. Seventeen comments mentioned various ways of checking their work and five comments mentioned using an easy problem to ensure that the mathematics would be correct.

The third question of the survey/questionnaire asked student how well they understood Polya's (1973) problem solving approach in general. They indicated roughly three levels of understanding: well, somewhat, and weak. The vast majority (20) felt they understood this process well. Three felt that they were weak in this set of skills while four indicated they understood problem solving somewhat or inconsistently.

To summarize, asking students to represent their understanding of a mathematical concept through creating a cartoon was a largely successful procedure. Students enjoyed the creative aspect of the assignment and the break from the usual assessment processes they had experienced in mathematics classes in the past. While doing something new and different can be anxiety-producing, as reflected in the fact that a number of students did not enjoy and even worried about their abilities to draw their cartoons, the overall response to the procedure was positive. Providing students with alternatives to drawing, such as cutting out images printed from the internet or even using a cartooning web app such as Toondo.com (n.d.) would probably address these concerns successfully.

Accuracy, a central value of mathematical thinking, seemed to be prized among the students and they took pains to ensure that their cartoons were accurate. Most students ensured accuracy by checking their work in various ways, such as creating charts, using a calculator, or having a friend check it. Some students opted for choosing an easy problem in order to ensure accuracy. When cartooning a less advanced idea, students reduce the cognitive load required to hold a mathematical concept in mind and represent it visually. If these students have spent most of their school careers memorizing algorithms, focusing on the complete understanding necessary for visual representation is possibly a process that is new to them which takes time to further develop. These students could probably progress to representing more challenging processes as they gain experience and confidence in this kind of thinking.

Implications of Cartooning in the Mathematics Classroom

In this first pass at implementing cartooning in the classroom, we found that students enjoyed the assignment to reflect their mathematical thinking in a cartoon. All the students who participated were part of the creation of successful cartoons that accurately reflected some aspect

of mathematics. In addition to being a good assessment of mathematical understanding, this assignment can also offer insight into the emotional content of students' approaches to mathematics. This is important, as we have seen, because learning is impeded by negative emotions.

We found that cartooning supported problem posing which is central to the ability to think about and apply mathematics to real world (or at least plausible real world, such as a world of aliens) situations. Cartooning as problem-posing is a rich area of inquiry. It would be interesting to find out if cartooning makes problem-posing easier or more difficult and also to find out what kinds of differences there might be between usual forms of classroom-based problem-posing and cartooned versions. Both problem-posing and cartooning require imagination and creativity; a question becomes, is there some kind of synergy that happens when students represent problems through cartoons?

A range of mathematical concepts and the reasoning behind them can be represented in cartoon form by students. An additional advantage to this procedure is that students who were comfortable with mathematics had the freedom to engage with concepts at their own level instead of needing to stay with the majority of the class, while students who were less confident and/or knowledgeable could also work at their own mastery level. Our students need more options for individualized learning and assessment than are typically available. Students who struggle need the opportunity to have success and advanced students benefit from the opportunity to engage at a level closer to their true understanding.

In this early stage of researching the use of cartooning in the mathematics classroom, pre-service teachers were given free reign as to their topic. Along with continuing to use cartoons with the pre-service teachers and expanding the ways in which this takes place, we are working with younger students and asking them to make their cartoons around specific, teacher-suggested topics, to see how that process works. It is hoped that this procedure will bear fruit in terms of extending mathematical reasoning, supporting the development of positive emotions around learning mathematics, and being a good assessment of a student's mathematical thinking.

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