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Understanding Students' Perceptions of Doing Mathematics: A Cultural Comparison

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Understanding Students' Perceptions of Doing Mathematics: A Cultural Comparison

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Abstract

Garnering different kinds of data from students about their perceptions of mathematics helps teachers, teacher leaders, districts and researchers better understand students' perceptions. In this study, we investigated and compared students' perceptions of doing mathematics from samples of students from the United States, China, and Fiji. We administered the Draw Yourself Doing Mathematics instrument to students at three grade levels in China, Fiji, and the United States of America. Statistically significant differences among perceptions in the three countries and the three grade levels were observed. Student drawings were further analyzed for other qualitative components, including factors affecting the learning environment, such as the presence of desks and working with others. Discussion is provided about the instrument's connection to other forms of perceptions research and implications for the use of the instrument by teachers, teacher leaders, and researchers.

Keywords: mathematics, student perceptions, student drawings, international comparison

Introduction

One of the many challenges that teachers face each year is building knowledge of who students are, their academic possibilities and attributes, and their perceptions of learning mathematics. Teachers may use a variety of sources for this information, including high-stakes test scores, previous course grades, or former teacher testimonies. Through these means, teachers begin to learn about their students' previous mathematical performance. Another important data point for teachers to understand is their student's perceptions of mathematical learning. Students will sometimes make revealing comments in class, in passing, or to their friends. They may demonstrate interest in mathematics during class time or through their engagement in class assignments. Teachers may also ask students directly about how they feel about mathematics or what they enjoy about it. Surveys are often used by teachers to garner information about students' perceptions of mathematics. Teachers use these tools to better understand the prior knowledge and perceptions of mathematics of the students entering their rooms with the goal to serve every student to the best of their ability.

In this paper, we explore another way to learn about students' perceptions of mathematics through the use of the 'Draw Yourself Doing Mathematics' instrument. Drawings may give different kinds of information than other ways of investigating students' perceptions. Some students are better able to explain their thoughts through drawings and give reasons why they hold the perceptions they do (Anim, 2012; Anning & Ring, 2004; Malchiodi, 1998). These drawings can then inform teachers and teacher leaders about the positive or negative perceptions students hold and may give details not gathered through other methods. Here, we share our research findings using drawings to inquire about students' perceptions of doing mathematics. These students are from schools in China, Fiji, and the United States. We then build upon this research to make recommendations for the use of the Draw Yourself Doing Mathematics instrument among teachers and teacher leaders.

Literature Review

At a very young age, children are encouraged to draw in order to develop their fine motor skills, stimulate their brains, and cultivate their creativity. Whether drawing lines and circles or drawing a picture of where the child lives, each picture tells the viewer something about the artist as well as "how they view the world" (Farland-Smith, 2012, p. 110). Drawings often reveal what the children enjoy or dislike. As items that represent elation or items that are more pejorative in nature are drawn, the children provide evidence about themselves and how they view the world. In drawings about mathematics, students may include items of elation such as smiles, thought bubbles of excitement when solving a problem, or grades of A++++. In contrast, they sometimes include items that are negative, such as weapons inflicting self-harm, defeated faces, or thought bubbles of discontent or hatred. The type and variance of these items make the drawings "multidimensional" (Farland-Smith, 2012, p. 109) and aid teachers and researchers to develop interventions for students. Borthwick (2011) shares that "psychologists and art therapists have used drawing for years as a way of gathering information about emotional and psychological aspects of children" (p. 38). Therefore, as many students are typically able to draw within the confinements of the classroom or art class, drawing is an understandable means of representing the daily aspects of their lives in and outside of the classroom (Farland-Smith, 2012).

Though using drawing as a tool to refine motor skills is unnecessary beyond the elementary grades, drawing can still be useful in gathering insight into a student's point of view of the world (Borthwick, 2011). As upper elementary, middle, and high school students are still developing their vocabularies and means of expression, using drawings to empathize and gage their perception of a situation can be very effective (Aguilar, Rosas, Zavaleta, Romo-Vázquez, 2016, Finson, Beaver, & Cramond, 1995, Weber & Mitchell, 1996). In support of this assertion, Briell, Elen, Depaepe, and Clarebout (2010) state, "drawings may provide a unique and valuable route of expression even for the older participant who might find it difficult to express such abstract beliefs in verbal or written words articulately" (p. 662), showing that drawing is a valuable tool to gain insights into students' worlds at all grade levels.

In addition to drawings being a viable tool for assessing students of varying ages, they also inform researchers about students' perceptions across cultures. Several studies conducted internationally include students as participants. Some examples include studies in Mexico (Aguilar et al., 2014), England (Borthwick, 2011), Belgium (Briell et al., 2010), Canada and Australia (Chamber, 1983), as well as in Finland and Russia (Räty, Komulainen, Skorokhodova, Kolesnikov, & Hämäläinen, 2011). However, only two of these studies compared drawings across cultures. Räty et al. (2011), comparing students' drawings of intelligence in Finland and Russia, found "cross-nationally shared" (p. 17) elements. Similarly, when comparing the drawings of French speaking versus English speaking Canadian students, Chambers (1983) found the drawings to be "very much alike" (p. 262). For example, Räty et al. (2011) found no significant difference ($p > 0.10$) for "the gender of the intelligent and the ordinary pupil drawn" (p. 9) between the Finish and Russian participants. Similarly, in his Draw-a-Scientist Test, Chambers (1983) found that a portion of the students in each of the three countries represented drew alternative representations of scientists such as Jekyll & Hyde or Frankenstein. Within these examples, there is evidence that researchers should be attentive to possible cultural meanings being conveyed by the students when exploring perceptions across cultures.

Analysis of student drawings can be focused on particular types of perceptions, including perceptions about attitudes toward mathematics. The study presented here further develops Bachman, Berezay, and Tripp's (2016) Draw Yourself Doing Mathematics Test in which students enrolled in a traditional introductory collegiate mathematics course and students enrolled in a course pairing mathematics and dance completed drawings at the beginning and conclusion of the semester. The samples were openly coded for affective elements indicating students' perceptions of doing mathematics. Numerical values were assigned to these open codes, which were used to score each sample. Bachman et al.'s (2016) results comparing pre-test and post-test scores of the students between classes showed the course to be effective in positively changing students' perceptions of mathematics.

The Draw Yourself Doing Mathematics Test heavily relied on the work of Chambers' (1983) and Finson et al. (1995) Draw-a-Scientist Test assessing children's stereotypical beliefs of scientists by asking them to simply draw what they believed a scientist looked like. Farland-Smith's (2012) Development and Field Test of the Modified Draw-a-Scientist Test and Draw-a-Scientist Rubric extended Finson et al.'s (1995) research by combining the drawings aspect with an additional set of questions asking for information about a student's drawing. This additional information eased the scoring process for the appearance, location, and activity categories.

Research involving students' drawings has been extended into Science, Technology, Engineering, and Mathematics (STEM) fields since the work of Chambers (1983). For example, Thomas and colleagues (2016) developed a rubric for assessing fourth and fifth-grade students' knowledge and understanding about the work of an engineer. Some extensions into the branch of mathematics parallel Chambers (1983) and Finson et al. (1995), such as assessing high school students' and adults' images of mathematicians (Aguilar et al., 2016; Rensaa, 2006). However, others diverged from the original test, extending the applications of drawing to include assessing the affective elements present as collegiate students draw themselves doing mathematics (Bachman et al., 2016), primary students' perceptions of and attitudes towards their mathematics lessons (Borthwick, 2011), and pre-service teachers' mental models of mathematicians doing math (Wescoatt, 2016).

With many possible extensions and applications, using drawings as a data source can be beneficial in education (Briell et al., 2010; Räty et al., 2011; Weber et al., 1996). Throughout these studies, drawings were deemed an effective tool for data collection. Briell et al. (2010) notes that there is a constant struggle for researchers looking to assess knowledge and that "finding creative and effective ways to bring individuals' knowledge to the surface and to allow thoughts or understandings to be shared in natural and meaningful ways" (p. 661) is important for epistemological research. Drawings are also a way to allow students to naturally express their perceptions of experiences that involve learning and growing new knowledge such as mathematics. As a data source, drawings are considered to be similar to text and frequently coded similarly (Weber et al., 1996). Consequently, we chose drawings as a way to inquire about students' perceptions derived from drawing themselves doing mathematics.

The objective of this research is to add to the research of Bachman et. al. (2016) from a global comparison perspective and use the Draw Yourself Doing Mathematics Tool in a new way.

Methods

Research Questions

In this study, the Draw Yourself Doing Mathematics instrument was used to investigate the following research questions:

1. RQ1: Are there any differences among students in the same grade level in the United States, Fiji, and China in perceptions of doing mathematics as measured by the Draw Yourself Doing Mathematics instrument?
2. RQ2: Are there any differences among students from different grade levels in perceptions of doing mathematics as measured by the Draw Yourself Doing Mathematics instrument?
3. RQ3: What are the similarities and differences among pictorial elements of the drawings from participants of China, Fiji, and the United States?

Participants

This study took place in three different countries: China, Fiji, and the United States of America. The 298 participants were students from grade 5, 8, or 10/11 who were taking mathematics courses in that grade. Table 1 shows the number of participants from each country and their respective grade levels. Each participant submitted only one drawing.

Instrument

The Draw Yourself Doing Mathematics Rubric was adapted from the coding process of Bachman et al. (2016). This rubric uses a seven-point Likert scale to assign a numerical value to each drawing. These numerical values also have corresponding categorical values: severely negative, negative, unpleasant, neutral, pleasant, positive, and extremely positive (Appendix A). The assignment of a specific numerical and categorical value is determined on a set number of positive and negative components within the drawing. The presence of negative components, confusion, frustration, overwhelmed, question marks, frowns, etc., correspond to lower scores of three or two. Expletives, statements of hate or other intense negative emotions, or negative actions acquire the lowest possible score of one. The presence of positive components, smile, positive thought bubble, indication of understanding, etc., receive scores of five or six depending on the frequency of the components. Similarly, elations, statements of love, and other intense positive emotions or actions receive the highest score of seven. Through these ordinal values, we establish the degree that participants positively or negatively perceive doing mathematics. Evidence for the ordinal value of the drawing was recorded as well as any additional comments pertinent to the sample. A copy of the rubric can be found in Appendix A, and a sample drawing for each ordinal value can be found in Appendix B.

Two aspects of traditional classrooms were also coded alongside the Draw Yourself Doing Mathematics Rubric. These aspects included whether students portrayed themselves working on mathematics with others and whether or not there was a desk or table present in the drawing (Kohn, 1999). The previously mentioned criteria were analyzed within and across the three different countries.

Procedure

Drawing upon the work of Bachman et al. (2016), we gave the participants the prompt "Draw yourself doing mathematics. Don't worry about the quality of your drawing. Just sketch what comes to mind." The researchers partnered with teachers from five schools across three nations to investigate their students' perception of doing mathematics. The first and second authors worked with teachers to administer the prompt to students without a time limit. Participants from the United States were given a piece of paper with only the prompt at the top. Similarly, participants from China were also given a piece of paper with both the English and Chinese translation of the prompt at the top. Finally, participants in Fiji were distributed a blank piece of paper, and the prompt, in English, was written on the whiteboard or projected on the interactive whiteboard at the front of the classroom. Teachers and authors distributing the assessment were instructed that all samples should remain anonymous. The participants did not write their name, student ID, or any other self-identifying markings on the prompt paper. Teachers were able to clarify that participants were able to include words to explain their drawings and that a drawing must be present, but not add their own explanation or instructions to the prompt. Following implementation, drawings were collected and numbered. Once all drawings were numbered and vetted, the rubric (Appendix A) was applied to the drawings.

The first two researchers in this project are native US citizens who have studied the education systems and cultures of China and Fiji. Their study of these systems included travelling to China and Fiji, interacting with students, teachers, and education professors, as well as visiting schools. Unlike the US and Fiji, China does not have English as a primary educational language. Therefore, prior to coding, drawings from China which contained any language or symbols other than English were interpreted by two linguistic and cultural experts. Both experts are native Chinese, have lived in both the United States and China, and speak both Chinese and English fluently. Any text in these drawings was translated into English, and any resulting cultural references were explained in person with the researchers.

To ensure the fidelity of rubric coding (Appendix A), the researchers conducted meetings for the purpose of establishing within-group interrater agreement. The researchers independently coded 10.4% of the data (31 of 298 drawings) with samples that were chosen using a random number generator. The expected minimum for interrater agreement is rwg = 0.9 (James, Demaree, & Wolf, 1993). Interrater agreement exceeded this minimum with rwg = 0.9355.

For RQ1 and RQ2, statistical methods were employed, which are further explicated in the data analysis section. Analysis for RQ3 occurred after coding with the rubric. The researchers used the process of open coding, which involved breaking down the data into first level categories of pictorial elements. These categories were tallied and agreed upon by the first two researchers. Categories were compared cross-nationally for similarities and differences among the drawings.

Data Analysis

Rubric scores were obtained for each drawing and grouped by each of the six classes studied. Excel was used to produce relative frequency histograms of rubric scores for each of the six classes. Minitab was used to compute basic descriptive statistics for each class, including sample size, mean, median, interquartile range, standard deviation, and 95% confidence intervals for the means and medians.

RQ1 and RQ2 are testing for evidence of a higher average positive perception level in a specific class than in another versus a null hypothesis of no difference. Therefore, we are using a series of one-tailed two-sample tests. Since the underlying distribution of scores is inherently ordinal in nature, the non-parametric Mann-Whitney test for difference in median was used as the primary test (Johnson & Kuby, 2012). The Mann-Whitney test does not have any normality assumptions on the underlying distribution. However, since all but one of the subgroups have sample sizes larger than 30 and the distributions of individual scores were examined to be mound shaped, the distribution of mean rubric scores is close enough to a normal distribution to be approximated well by a normal curve. This satisfies the assumptions for a *t*-test; thus, one sample *t*-tests were used to provide corroborating evidence of a positive difference in mean. An alpha level of 0.05 was used for all hypothesis tests. Mann-Whitney and *t*-tests are standard hypothesis tests discussed in many entry level statistics texts such as Johnson and Kuby (2012).

Results and Discussion

Summary statistics mentioned above for each class were computed in Minitab and are tabulated in Table 1.

Table 1
Summary Statistics for Rubric Scores by Country and Grade Level

	United States			Fiji		China
Grade	5	8	10-11	5	8	8
Sample Size	18	52	44	39	37	108
Median	4.5	4.0	4.0	4.0	4.0	3.0
	[4.0, 5.0]	[4.0, 5.0]	[4.0, 4.0]	[4.0, 5.0]	[3.0, 4.0]	[3.0, 4.0]
Mean	4.6	4.3	3.8	4.2	3.5	3.2
	[4.2, 5.0]	[3.9, 4.6]	[3.4, 4.3]	[3.9, 4.6]	[3.1, 4.0]	[3.0, 3.5]
IQR	1	1	2	1	2	2
Standard Deviation	0.85	1.21	1.61	0.99	1.26	1.35

Note: Intervals are 95% confidence intervals.

RQ1: Are there any differences among students in the same grade level in the United States, Fiji, and China in perceptions of doing mathematics as measured by the Draw Yourself Doing Mathematics instrument?

Figure 1 shows the relative frequency histograms for the distribution of rubric scores for each of the data groups. The rows of the figure are organized by the same grade level, whereas the columns are organized by country of origin. A visual inspection of the histograms indicates that for the same grade level, perceptions of doing mathematics in the United State are higher than those in Fiji, and those in Fiji are higher than those in China. This is also evidenced by the mean scores of both the fifth-grade participants: United States 4.6 and Fiji 4.2, and the eighth-grade participants: United States 4.3, Fiji 3.5, China 3.2 (Table 1, Figure 2). However, hypothesis tests had to be performed to determine if these differences were statistically significant.

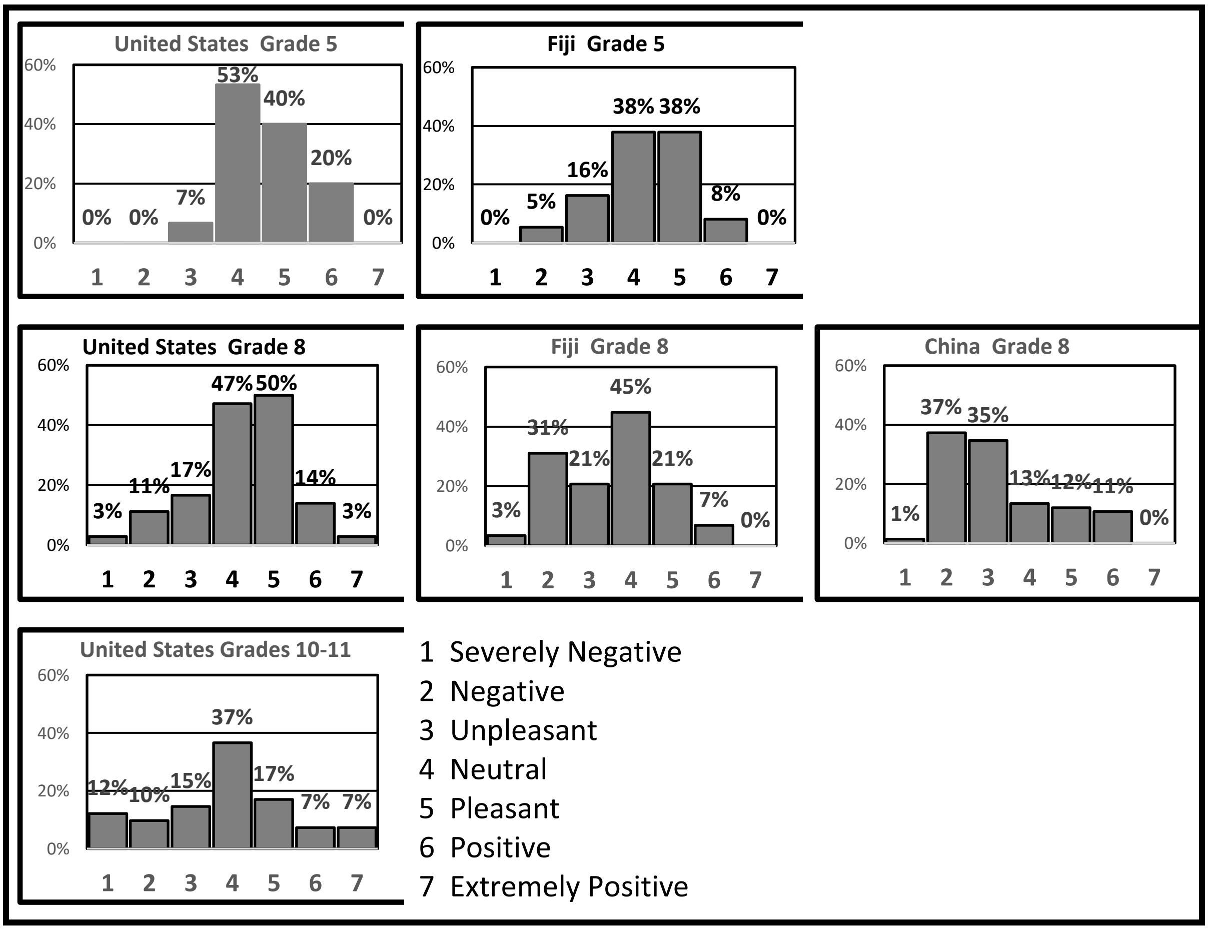


Figure 1. Relative Frequency Histograms of Rubric Scores by Country and Grade Level.

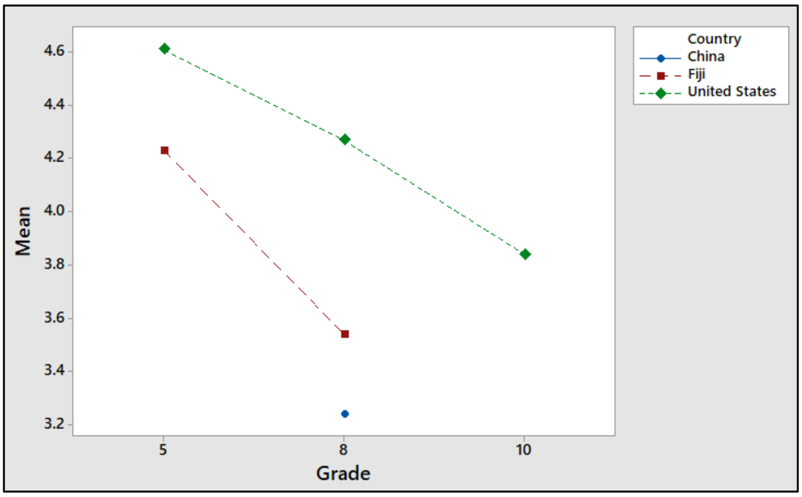


Figure 2. Graphical Comparison of Mean Rubric Scores by Grade and Country.

Table 2 provides the *p*-values for tests for significance of differences in the centre for the four possible pairings of data groups at the same grade level with significant results in boldface. In each case, the test is for the first group to have a higher centre than the second group. From the *p*-values of the Mann-Whitney tests, we see that the eighth-grade US participants scored significantly higher than their counterparts in either Fiji (p = 0.004) or China (p = 0.000). Comparing US fifth graders to Fiji fifth graders produced a *p*-value of 0.112, and comparing Fiji eighth graders to China eighth graders produced a *p*-value of 0.098. Therefore, the data for these pairings were not significantly higher at this alpha level.

Table 2

One-tailed Hypotheses Tests Pairs of Subgroups

Groups Compared	Mann-Whitney (*p*-value)	*t*-test (*p*-value)
US 5 vs. Fiji 5	0.112	0.099
US 8 vs. Fiji 8	**0.004**	**0.004**
Fiji 8 vs. China 8	0.098	0.112
US 8 vs. China 8	**0.000**	**0.000**

For these schools at the eighth-grade level, there is enough evidence to support the conclusion that participants in the US have more positive perceptions of doing mathematics as measured by this instrument than their counterparts in either Fiji or China. Although there is some evidence to suggest that fifth-grade US participants also have more positive perceptions than their counterparts in Fiji and that eighth-grade Fijian participants have more positive perceptions of doing mathematics than their counterparts in China, the evidence provided here is not strong enough to reach these general conclusions.

RQ2: Are there any differences among students from different grade levels in perceptions of doing mathematics as measured by the Draw Yourself Doing Mathematics instrument?

We present data from three different data grade levels from the US and two from Fiji. In both countries, we see decreasing mean rubric scores as the grade level increases (Table 1, Figure 2).

This, along with a visual inspection of the histograms from each country in Figure 1, suggests that, as students progress through school, their perceptions of doing mathematics become more negative on average. The results of the Mann-Whitney tests found in Table 3 determine whether the data indicate significant support to reach this conclusion.

Table 3
One-tailed Hypotheses Tests Pairs of Subgroups

Groups Compared	Mann-Whitney (*p*-value)	*t*-test (*p*-value)
US 5 vs. US 8	0.188	0.099
US 8 vs. US 10-11	0.053	0.075
US 5 vs. US 10-11	**0.022**	**0.009**
Fiji 5 vs. Fiji 8	**0.007**	**0.005**
US/Fiji 5 vs. US/Fiji 8	**0.049**	**0.020**
All 5 vs. All 8	**0.000**	**0.000**

The test comparing the scores of all fifth graders to all eighth graders indicates that fifth graders scored significantly higher than eighth graders ($p = 0.000$). When this data is limited to the countries for which we have measures in both grades (US and Fiji), fifth graders still score significantly higher ($p = 0.049$). When we compare results within each country, we see similar, but not as strong evidence, that younger students score higher on this rubric. The data gives evidence that US fifth-grade participants have significantly more positive perceptions of doing mathematics than US tenth-eleventh grade participants ($p = 0.022$). Fiji fifth-grade participants also have significantly more positive perceptions about doing mathematics than the Fijian eighth-grade participants ($p = 0.007$). However, the comparisons of US fifth-grade participants to US eighth-grade participants ($p = 0.188$) and US eighth-grade participants to US tenth-eleventh-grade participants ($p = 0.053$) are not statistically significant at the $\alpha = 0.05$ level.

Overall, there is strong evidence to suggest that the fifth graders' perceptions are more positive than eighth graders' perceptions. This is further reinforced by comparisons of scores at each grade level within each of the countries. In the case of US participants, there is enough evidence to support the conclusion that participants in the fifth grade have more positive perceptions of doing mathematics as measured by this instrument than participants in the tenth-eleventh grade. Similarly, there is enough evidence to support the conclusion that Fijian fifth-grade participants are more positive about their perceptions of doing mathematics as measured by this instrument than Fijian eighth-grade participants. Although there is some evidence to suggest that US fifth-grade participants also have more positive perceptions than eighth-grade participants and US eighth grade participants have more positive perceptions than tenth-eleventh grade participants, the evidence provided here is not strong enough to reach this general conclusion.

We note that if two-tailed tests had been used in each of the analyses above, the *p*-values would have been twice as large. However, the analysis of the data would not lead to different conclusions. Similarly, had *t*-tests been used instead of Mann-Whitney tests no differences in conclusion would have been reached.

RQ3: What are the similarities and differences among pictorial elements of the drawings from participants of China, Fiji, and the United States?

The following pictorial elements were coded during the analysis process: traditional aspects of the classroom, presence of a facial expression, real world applications, and cultural references. Briell et al. (2010) noted how drawings are "a rich source of information" (p. 662) and include the setting, physical space, and objects in one mental image. Therefore, to reveal information regarding the setting of the participants' drawings, traditional aspects of the classroom were also recorded. The number of people present in the drawing was recorded, and the mean and median were calculated for each data group. The presence of a desk within the drawing was indicated with a one if present or a zero if not. The percentage of drawings with a desk was calculated for each data group (Table 4).

Table 4
Summary Statistics for Drawing Aspects by Country and Grade Level

	United States			Fiji		China
Grade	5	8	10-11	5	8	8
Sample Size	18	52	44	39	37	108
Mean # People	1.39	1.60	1.09	1.08	1.22	1.04
Median # People	1	1	1	1	1	1
Percentage of Desks	83.3	69.2	93.2	94.9	78.4	69.4

Other Observations about Student Drawings

Certain components of drawings were consistent throughout the data groups. When analyzing the total sample of drawings (n = 298), more patterns emerged, including facial features, perspective, and the number of people. When considering the facial features of the drawings, some participants included expressions, and many did not. There were 63 drawings (21%) that did not include a facial expression, of which 50 of the 63 (79%) received a "neutral" score. The inclusion of a facial expression was a key factor in discerning whether the student perceived doing mathematics positively or negatively. The remaining drawings included additional components, which allowed for further interpretation of the drawings. Three subcategories emerged from those drawings that did not include facial expressions: stick figures (28/298 = 9%), back to audience (27/298 = 9%), and hands only (5/298 = 2%) (Figure 3). Stick figures with circles for heads without faces accompanied by math figures in thought bubbles or around the person allowed for 6 of the 28 (21%) drawings to receive an "unpleasant" score and 2 of the 28 (7%) to receive a "pleasant" score. Participants who drew people with their backs to the audience varied in the detail of their drawings. Added detail allowed for 5 of the 27 (19%) drawings to receive a score other than "neutral". Finally, participants that drew only hands performing math calculations all received a "neutral" score of four as the drawings showed no other signs about the students' perceptions of doing mathematics.

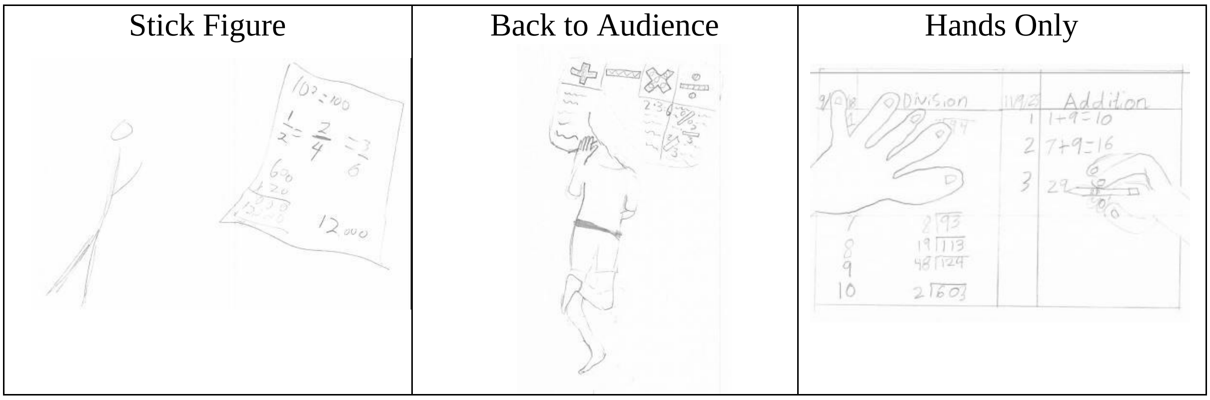


Figure 3. Examples of Drawing Characteristics

Another trend throughout the data groups was the presence of multiple figures drawn in a single drawing (49/298 = 16%). The participants who drew multiple figures fell into two categories: those who drew images of multiple unique people (34/49 = 69%) and those who drew a single unique person multiple times (15/49 = 44%) (Figure 4). The vast majority of the multiple unique people type drawings (32/34 = 94%) included images of other students and/or a teacher. Participants with drawings of this type tended to have more positive perceptions of doing mathematics (23/34 = 68%) compared to those who had negative perceptions (11/34 = 32%). When a participant drew multiple images of a single unique person (15/49 = 31%), the majority portrayed the person as having mixed feelings about mathematics (10/15 =67%), meaning the drawings contained both positive and negative perceptions. A majority of these drawings had the structure of a comic in which a single person is in multiple scenarios (12/15 = 80%).

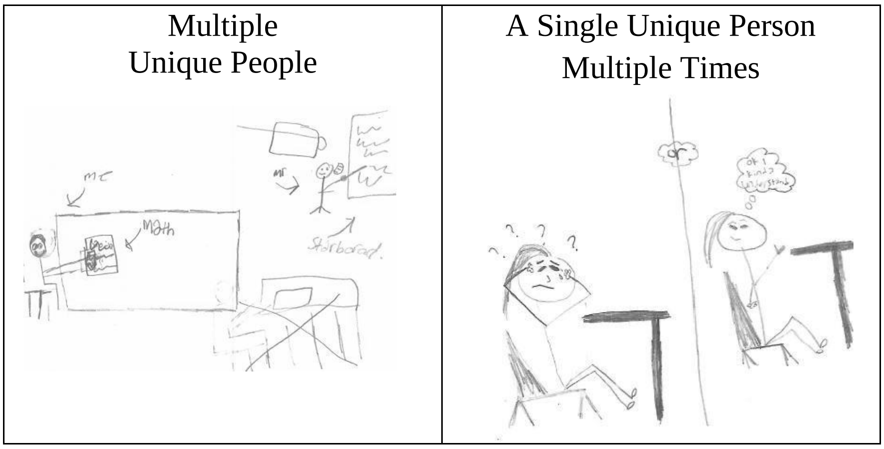


Figure 4. Examples of Drawings with Multiple Figures

There were two other categories that had rare occurrences but are worthy of mentioning: real world scenarios and cultural references. A few participants (3/298 = 1%) drew real-world scenarios to portray themselves doing mathematics (Figure 5). Firstly, an eighth-grade student from the United States drew about using fractions to bake at home. Next, an eighth-grade Fijian student drew about calculating prices while checking out at a store, and finally, a tenth-grade student from the United States drew about using right triangles to find the dimensions of a house. No drawings from the Chinese eighth-grade participants appeared to reference any real-world scenarios.

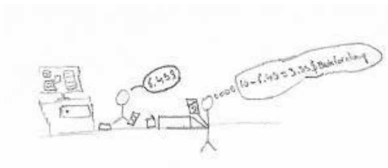
US 8 Cooking	Fiji 8 Shopping	US 10/11 Measuring
		

Figure 5. All Examples of Real-World Scenarios in Drawings

Two samples also portrayed noteworthy cultural references. The first, from a Chinese participant, shows a person working alone at a desk (Figure 6). There is an arrow pointing from their work to some text in Chinese. When translated, the text reveals the name of a famous school who designs practice questions for an important mathematics examination given in China. This drawing scored a three due to the frown, sweat on the forehead, and slightly angry facial expression, interpreted as his frustration with these questions and the upcoming tests. The second sample, from a high school participant in the United States, included pop cultural references (Figure 6). The participant mentions how he/she wishes to insert a GIF, a brief self-repeating video or animated image, of a scene from a recent animated movie. In the scene, the main character is out of ideas saying, "useless… empty… brain…" as he pounds his head on the table. This drawing received the lowest score possible, a one, as the participant was referencing a character that was injuring himself.

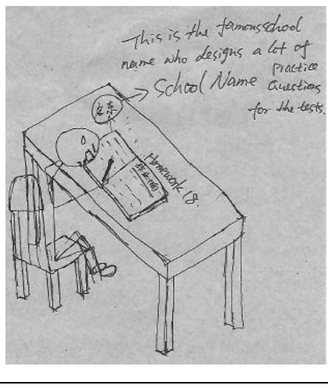
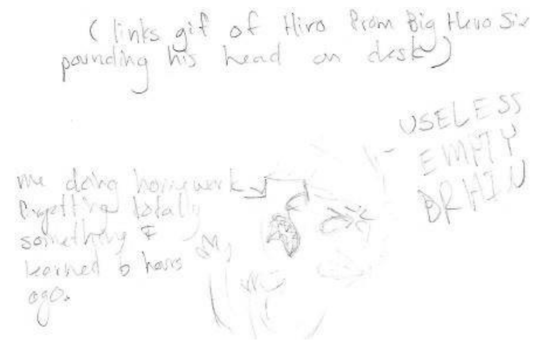
Chinese Cultural Reference	US Cultural Reference
	

Figure 6. Examples of All Drawings with Cultural References

Discussion

In our analysis, we noted that there are significant differences in the perceptions of doing mathematics between certain data groups. Firstly, we concluded that there was a significant difference between the perceptions of doing mathematics between the US 8 and Fiji 8 data groups, with the US 8 data group having significantly better perceptions of doing mathematics than their counterparts in Fiji (p = 0.004). While each country and school's macro and micro cultures likely inform these perceptions, another possible explanation for this difference might be the curriculums being used by the teachers. For example, in the US 8 data group, the teachers use the Connected Mathematics Project (CMP) curriculum, which allows problem-based learning in small group settings (Cain, 2002). Such classroom settings used throughout their middle school experiences may tend to give students higher perceptions of mathematics.

These findings have led us to consider that more research and development is needed to understand the differences between the typical Likert-scale measures involving constructs such as self-efficacy and self-concept, and the drawing-type measures like the one used in this study. We noticed in our analysis of the drawing measure that students having a simple prompt to draw themselves doing mathematics allowed for different data to be gathered than could be achieved with more direct statements afforded by Likert-scale surveys. There are benefits to both types of measures, and it is our intention to do more focused empirical research about the similarities and differences in data collected from students.

Similar comparisons show that students' perceptions of mathematics significantly worsen in the US between the fifth grade and tenth-eleventh grades (p = 0.022) as well as in Fiji between the fifth and eighth grades (p = 0.007). From these findings, we wonder if larger scale research studies involving drawings would align with the idea that when students do not perform well, their perceptions tend to be more negative about mathematics. Longitudinal research in the United States has shown that students' achievement in mathematics decreases as they progress through high school (Campbell, Voelkl, & Donahue, 1997). More research is needed to determine if there is a correlation between the Draw Yourself Doing Mathematics assessment, student achievement, and student mathematical efficacy. Other factors, such as student self-efficacy, the impact of technology, or classroom environment, might play a role but cannot be reported in this study.

The data represented in Table 4 show that participants are typically only drawing a single unique person in their drawings across all countries and grade levels (264/298 = 89%). Though each data group had some drawings with multiple unique people, as noted by the fact that the arithmetic mean is greater than one, a median of one across all counties gives evidence that participants are possibly perceiving themselves as being alone when doing mathematics. We note that there may be prompt bias when stating "draw yourself" implying that there should only be one person in the drawing. However, it is interesting to note that 11% (34/29) of the drawings included more than one person. Table 1 also shows that participants are not only alone but at a desk or table over 69% of the time. Though these data points include drawings of multiple unique people, these percentages show that participants are visualizing themselves confined to their desk when they are doing mathematics, even if there are other people present.

When comparing these percentages within countries and grade levels, further research questions arise. First, when looking at the percentage of desks across grades within the United States, we see that the percentage starts high at 83% in the fifth grade, decreases to 69% in the eighth grade, then increases to 93% in tenth-eleventh grades. These results illuminate further questions about why there is such a decrease in the eighth grade. Are there classroom related factors causing this decrease? Anecdotally, one researcher observed that the US eighth-grade classroom used the Connected Mathematics Project (CMP) curriculum. CMP contains many tasks in which students are able to work together. Prior to the beginning of the research project, a project member observed four classroom sessions of the US eighth-grade teacher. These observations revealed students working together often using established norms for presenting in the classroom. These classroom related factors may have caused the presence of desks in these drawings to decrease, as well as the arithmetic mean for the number of people present in the drawings to increase. The percentage of drawings containing desks from Fijian participants decreased from 95% (5/57) in the fifth grade to 78% (154/197) in the eighth grade. An anecdotal observation and discussion with the teacher may again illuminate reasons for this decrease. In an observation of the teaching in this classroom, the first author noted that the teacher allowed students to work out of their desks, often pushing them to the edges of the classroom at the beginning of the period. The teacher further explained that his philosophy of teaching included students actively learning outside the confines of their desks.

Conclusion

In this study, we looked at students' perceptions from different countries and cultures. Our research shows that drawing yourself doing mathematics can provide interesting insights into students' perceptions. The assessment worked robustly in each country and revealed similar positive and negative perceptions that some students hold when they do the work of mathematics. In summary, RQ1 revealed that the eight-grade students in the US had more positive perceptions of doing mathematics than their Chinese and Fijian peers, but this was not the case for the fifth-grade students. For RQ2, there is evidence to warrant that as students progress through school, their perceptions of doing mathematics become less positive. Specific to the nations and grades studied here, this degradation of perception occurs in the US between 5^{th} grade and high school and in Fiji between the fifth grade and eighth grade. RQ3 gave insights that a great number of students from all nations understand the doing of mathematics taking place in a school setting. Although there are a few exceptions of doing mathematics in the world outside the school, most students from each nation included some element of a school setting in their drawing of doing mathematics. This perhaps is not a surprising result given the focus on mathematics in school and not in other parts of society.

Students revealed far more negative items in their drawings than positive across all cultures and grade levels. We also found some interesting details of the possible impact of certain learning environments, as evidenced by the appearance of certain elements in the drawings, including the presence or absence of desks, additional people, cultural references, and real-world scenarios. Across cultures and grade levels, most of the drawings consisted of the student working alone at a desk. Teachers may be able to use drawings to help them identify the effect of their teaching strategies.

It would be interesting to combine this drawing task with other methods in a broader range of students from these countries to see if these results are indicative of the broader cultures of which these students were a part. If these results are indicative of students in general, then they illuminate challenges for teachers, especially those of older students, to try to find ways of reducing the generally negative attitudes about mathematics, particularly as students age. Identifying cultural differences provides opportunities for learning from other cultures.

Implications for Teachers and Instructional Leaders

Teachers and teacher leaders may use the Draw Yourself Doing Mathematics Test to know more about students' perceptions of mathematics as well as revelations about the students' themselves (Farland-Smith, 2012). For example, when some students' drawings revealed that doing mathematics make them want to invoke some kind of "self-harm", then this acts as an important signal to teachers to plan instructional time devoted to creating and conversing about a safe space for these students to engage in mathematics. On the other end, some students' drawings revealed specific details about how excited they were and how proud it made them feel when they could solve mathematics problems on their own. Knowing which students experience problem solving this way allows the teacher to work with those students to nurture a classroom culture in which more and more students enjoy mathematical problem solving.

Another implication that we draw from this research is that implementing the Draw Yourself Doing Mathematics Test is simple yet highly informative. The assessment only took students between 5 and 7 minutes to complete. Similarly, applying the rubric took an average of 20 minutes for a classroom sized sample of 25 to 30 drawings. As mentioned in the literature review, there are benefits for utilizing drawings as opposed to written explanations, especially for younger students. Furthermore, the data analysis in this study shows that participants in this study were nearly twice as likely to have a decidedly negative perception of doing mathematics than a decidedly positive one, with 18% (55/298) of the drawings receiving the lowest scores of "severely negative" and "negative" and only 9% (28/298) receiving the highest scores of "positive" and "extremely positive". Teachers and teacher leaders who use the Draw Yourself Doing Mathematics prompt might compare the results to our findings to be informed about their students' perceptions and make decisions on how to improve those perceptions. The analysis also revealed that participants who drew images containing themselves doing mathematics with others were more than twice as likely to have a positive perception (23/34 = 68%) of doing mathematics than those with negative perceptions (11/34 = 32%). This evidence supports the implication that doing mathematics with others tends toward helping students yield a more positive disposition toward mathematics, a desired aspect for mathematics educators (Kilpatrick, Swafford, & Findell, 2001).

In our conversations with teachers after implementation of the assessment, we noticed an excitement to see whether aspects of their teaching philosophy, such as allowing students to work with peers and not be confined to their desks, were prevalent in students' drawings. Therefore, this assessment not only serves as a means of assessing students' perceptions of doing mathematics but also as encouragement for teachers to reflect on aspects of their own teaching.

Another aspect the prompt allows for is collaboration with teachers of other disciplines. We find it beneficial to work with colleagues, and in the case of the Draw Yourself Doing Mathematics prompt, there is much potential to work with an art or language teacher in meaningful ways. Art teachers typically provide instruction and guidance about topics that would improve students' ability to express themselves through drawing. The enactment of the students using the drawing assessment in conjunction with their instruction about techniques related to drawing people may enrich the data gathered by mathematics teachers while providing a space for students to explore their artistic skill and creativity. Similarly, while working alongside teachers of language and writing, it is conceivable that a written prompt could be given that asks students to write about what it is like to do mathematics. The students' drawings and writing could then be used to triangulate data about students' perceptions of doing mathematics in addition to the assessment of students' writing and drawing proficiency. Of course, in younger grades, when a single teacher engages students in all these topics within a self-contained classroom, it is more feasible to do all three things.

Limitations

The data for the study was gathered from a sample of students at schools which were familiar to the researchers. Relative to each nation in this research, these samples are small, and it cannot be known if they are representative of the countries as a whole. Use of country names in this article is only for the purpose of categorical necessity and not used to imply that these results are indicative of students in each nation as a whole.

Final Note

Drawing assessments hold a lot of promise in identifying student perceptions (Chambers, 1983). The Draw Yourself Doing Mathematics Test can be easily implemented by teachers and teacher leaders. The assessment allows teachers to have a window into their students' ideas and experiences about "doing mathematics". When teachers know more about their students' experiences, they can make more informed decisions about how to approach individual students based on their perceptions and better plan classroom instruction to improve student perceptions. Perhaps our global society can work together to investigate ways to improve students' perceptions of mathematics.

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References

Anim, J. O. (2012). *The role of drawing in promoting the children's communication in Early Childhood Education* (Master's thesis). Retrieved from www.hioa.no/content/download/24993/319284/file/Joyce.pdf

Anning, A., & K. Ring. (2004). *Making Sense of Children's Drawings.* Maidenhead: Open University Press.

Aguilar, M. S., Rosas, A., Zavaleta, J. G. M., & Romo-Vázquez, A. (2016). Exploring high-achieving students' images of mathematicians. *International Journal of Science and Mathematics Education*, *14*(3), 527-548.

Bachman, R., Berezay, K., & Tripp, L. (2016). Draw yourself doing mathematics: Assessing a mathematics and dance class. In Adolphson, K. V. and Olson, T. A. (Eds.) *Proceedings of the 43rd Annual Meeting of the Research Council on Mathematics Learning*. Orlando, FL.

Borthwick, A. (2011). Children's perceptions of, and attitudes towards, their mathematics lessons. In Smith, C. (Ed.) *Proceedings of the British Society for research into learning mathematics*, *31*(1), 37-42.

Briell, J., Elen, J., Depaepe, F., & Clarebout, G. (2010). The exploration of drawings as a tool to gain entry to students' epistemological beliefs. *Electronic Journal of Research in Educational Psychology, 8*(2), 655-688.

Cain, J. S. (2002). An evaluation of the connected mathematics project. *The Journal of Educational Research, 95*(4), 224-233.

Campbell, J. R., Voelkl, K. E., & Donahue, P. L. (1997). NAEP 1996 Trends in Academic Progress. Achievement of US Students in Science, 1969 to 1996; Mathematics, 1973 to 1996; Reading, 1971 to 1996; Writing, 1984 to 1996.

Chambers, D. W. (1983). Stereotypical images of the scientist: The Draw-a-Scientist test. *Science Education, 67*(2), 255-265.

Farland-Smith, D. (2012). Development and field test of the modified Draw-a-Scientist Test and the Draw-a-Scientist Rubric. *School Science and Mathematics, 112*(2), 109-116.

Finson, K. D., Beaver, J. B., & Cramond, B. L. (1995). Development and field test of a checklist for the Draw-a-Scientist Test. *School Science and Mathematics, 95*(4), 195-205.

James, L., Demaree, R., & Wolf, G. (1993). R_{wg}: An assessment of within-group interrater agreement. *Journal of Applied Psychology, 78*, 306-309.

Johnson, R., & Kuby, P. (2012) *Elementary Statistics, Eleventh Edition*. Boston, MA, Brooks/Cole Cengage Learning.

Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it up: Helping children learn mathematics*. Washington, DC: National Academy Press.

Kohn, A. (1999). *The schools our children deserve: moving beyond traditional classrooms and "tougher standards"*. Boston: Houghton Mifflin Co.

Malchiodi, C. (1998). *Understanding children's drawings*. London: Jessica Kingsley.

Räty, H., Komulainen, K., Skorokhodova, N., Kolesnikov, V., & Hämäläinen, A. (2011). A picture is worth a thousand words: a comparison of pupils' images of intelligence in Finnish and Russian Karelia. *Social Psychology of Education*, *14*(1), 1-22.

Rensaa, R. J. (2006). The image of a mathematician. *Philosophy of Mathematics Education Journal*, *19,* 1-18.

Thomas, J., Colston, N., Ley, T., DeVore-Wedding, B., Hawley, L. R., Utley, J., & Ivey, T. (2016). Developing a rubric to assess children's drawings of an engineer at work. *Proceedings of the 123rd Annual Conference & Exposition of the American Society of Engineering Educators.* New Orleans, LA.

Weber, S., & Mitchell, C. (1996). Drawing ourselves into teaching: Studying the images that shape and distort teacher education. *Teaching and Teacher Education*, *12*(3), 303-313.

Wescoatt, B. (2016). Exploring mental models of "doing math" through drawings. In Adolphson, K. V. and Olson, T. A. (Eds.) *Proceedings of the 43rd Annual Meeting of the Research Council on Mathematics Learning*. Orlando, FL.

Appendix A

"Draw Yourself Doing Mathematics" Rubric

Student Number:__________________________ Country of origin:____________ _____________

Numerical Value:	Categorical Value:	Indicators:	Evidence from Sample:
1	Severely Negative	At least one of the following: expletives, statements of hate (e.g. "I hate math"), intense crying, vomiting, suicide attempts, display of failing grade, or another communication of intense anger or sadness.	
2	Negative	At least two negative components (e.g. confusion, frustration, overwhelmed, question marks, frowns, etc.)	
3	Unpleasant	At least one negative element (e.g. confusion, frustration, overwhelmed, question marks, frowns, etc.) and **no** positive elements	
4	Neutral	Communicated no clear positive or negative emotion (e.g. flat line mouth)	
5	Pleasant	At least one positive element (e.g. smile, positive thought bubble, indication of understanding, etc.) and no negative elements	
6	Positive	At least two positive elements (e.g. smile, positive thought bubble, indication of understanding, etc.)	
7	Extremely Positive	At least one of the following: elations, statements of love e.g. "I love math", intense cheering, hearts or other imagery, successful grades, or another communication of strong happiness	
Additional Comments:			

Numerical value, interpretation of numerical value, and indicators adapted from Bachman, R., Berezay, K., and Tripp, L. (2016). Draw Yourself Doing Mathematics: Assessing a Mathematics and Dance Class. In Adolphson, K. V. and Olson, T. A. (Eds.). Proceedings of the 43rd Annual Meeting of the Research Council on Mathematics Learning. Orlando, FL.

Appendix B

Examples of Student Drawings for Each Rubric Level

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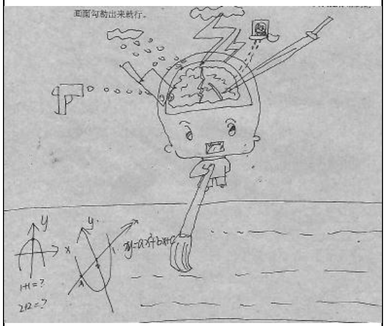
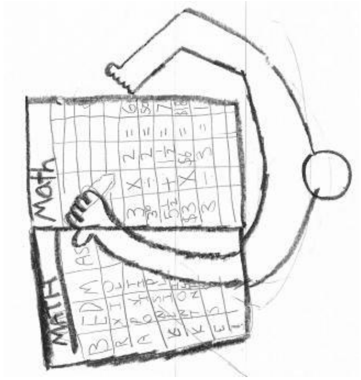
</td>
<td>(2, Negative)
</td>
<td>(3, Unpleasant)
</td>
</tr>
<tr>
<td>(4, Neutral)
</td>
<td>(5, Pleasant)
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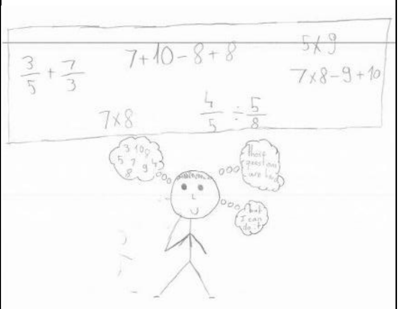
<td>(6, Positive)
</td>
</tr>
<tr>
<td>(7, Extremely Positive)
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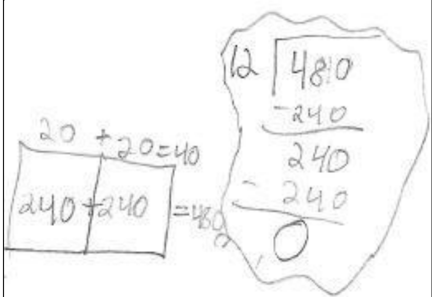
<td>Sample that revealed no information about student's perceptions of doing mathematics
</td>
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