IMPROVING THE PERCEIVED VALUE AND AFFECT OF STATISTICS IN ELEMENTARY AND MIDDLE SCHOOL TEACHERS THROUGH THE DEVELOPMENT OF PEDAGOGICAL CONTENT KNOWLEDGE

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As Arthur Benjamin discusses in his TED talk (www.ted.com), statistics is often undervalued because we live in a society where mathematics curriculum follows a path from arithmetic, to algebra, and finally to calculus. Many elementary and secondary educators do not deem it worthy of substantial focus in their classrooms, and therefore thousands of college students struggle through statistics courses as they try to build on an unstable foundation. Research from an intensive professional development program for 4th-8th grade teachers in which increases in perceived value and affect were achieved through a focus on pedagogical content knowledge is presented. Included are teacher journal entries, discussion of program development, and implications for future research and practice.

BACKGROUND

The new Common Core State Standards (CCSS), which replaced the individual state standards in 49 states across the United States, emphasize what they call *operations and algebraic thinking* beginning in kindergarten, placing students on a calculus-based trajectory for school mathematics as soon as they enter our classrooms. Even though the CCSS places a stronger emphasis on data analysis leading to statistics than many states did in the past, the standards' focus still falls towards the traditional mathematics curriculum (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). Although the knowledge of calculus is important in many professions, the calculus track has been so engrained within our educational system that even with the new emphasis that the CCSS places on data analysis and statistics, assessments still focus overwhelmingly on the algebra standards, sending the signal to many teachers that they need not spend significant time or effort inside, or outside, of their classrooms on statistics content.

A recent report on the need for statistics education graduate programs noted, "There is a great need to prepare elementary and secondary teachers who understand statistics at a reasonably deep level in order to teach ideas of data and chance to their students" (Garfield, Pantula, Pearl and Utts, 2009, p. 17). For many mathematics teachers their only experience with statistics is in an introductory statistics course taken at the undergraduate level (Burrill & Romburg, 1998; Garfield & Ben-Zvi, 2008). However, these courses are not focused on developing pedagogical content knowledge; thus, teachers enter the classroom unprepared to teach statistical concepts to their students because they often remember statistics solely as a series of memorized formulas and procedures. Because the background knowledge of many teachers relies heavily on these experiences in introductory college courses, their ability to effectively deliver statistics content is often diminished. In addition, because many teachers experienced a statistics course that was tedious and difficult, they hold negative attitudes about the subject and need experiences that dispel those attitudes. A negative attitude towards statistics can subconsciously cause teachers to devalue the importance of this topic in the mathematics education of their students (Estrada & Batanero, 2008; Estrada, Batanero, & Lancaster, 2011; Groth 2007).

PROGRAM DEVELOPMENT

In the spring and summer of 2013, fourteen middle grades mathematics teachers (grades 5-8) participated in nine, six-hour professional development sessions focused on the statistics and probability strand of the CCSS. In addition, independent evaluators observed each of the teachers in their classrooms, at least once, throughout the professional development series. The majority of the participants in this program reported that they had completed only two college mathematics or statistics courses, with a median of three courses. The goal of this professional development program was to increase the participants' understanding of statistics and their design and delivery

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of quality statistics instruction. These participants were randomly selected from a larger population of teachers within an urban school district outside of Atlanta, Georgia and were part of a larger multiyear Mathematics and Science Partnership Program grant. This paper solely focuses on the development, implementation and outcomes of the nine, six-hour sessions of statistics and probability professional development.

The development of this program relied heavily on the Guidelines for Assessment of Instruction in Statistics Education Report (GAISE; Franklin et. al., 2007), the CCSS, and the Progressions for the Common Core State Standards in Mathematics (Common Core Standards Writing Team, 2011). After having thoroughly reviewed each of these documents, the focus became helping teachers better understand what GAISE calls "the investigatory process," as well as the corresponding concepts that support statistical investigation. This process was explicitly discussed during the first session of the professional development program. However, because of its importance, participants were required to complete their own statistical investigation on a topic of their choosing. They were given time during several sessions to work on the project and share their progress and gain feedback from their peers. On the final day of the program each person presented his/her findings.

The final list of session topics were as follows:

- Measures of Center
- Measures of Spread
- Measures of Relative Standing
- Sampling Techniques and Distributions
- Linear Correlation and Regression
- The Role of Probability in Statistics

These topics were selected to not only cover the major concepts taught in the middle grades, but also included topics, such as sampling techniques and distributions, that would push teachers understanding of statistics beyond the level at which they were required to teach.

SESSION STRUCTURE

The structure of each session was essentially the same. Participants began by answering a question related to their background knowledge on the topic of the day. For example, at the beginning of the measures of center session participants were asked to answer the question, "What do you know about mean, median, and mode?" The purpose of these opening questions was to allow participants to think about their own conceptions of the topic prior to engaging in activities and discussions that were designed to change these previous conceptions. The teachers' responses enabled the facilitator to gain insight into the participants' current level of understanding

Participant responses were varied, but the majority fell into three categories. The first commonality in their writing was a focus on formal, traditional definitions of the concepts. For example, one participant wrote in her journal, "Mean is the average of the numbers. Median is the middle number. Mode is the number you see most often." In addition, participant responses brought to light misconceptions or lack of understanding held about the topic. At the beginning of the session about linear correlation and regression, one participant wrote, "Linear correlation means it lines up. It is in line with the other numbers, thoughts, etc. Not sure how it relates to regression." Another wrote, "Regression takes place when the data does the opposite. It doesn't correlate." Finally, participants expressed where they were lacking in knowledge of the topic. At the session about measures of spread, a teacher wrote, "I have limited understanding of standard deviation and really just learned about mean absolute deviation this year to teach it."

After participants had sufficient time to answer the opening question, they were presented with an engage activity designed to showcase the topic of the day and activate any prior knowledge. The structure of one engage activity that was used in the sessions is described below.

Sample Engage: Mean and Median

This engage asked participants to complete a released item from the National Assessment of Education Progress (NAEP). Once participants completed this item individually, they then discussed their answers with their tablemates. The purpose of selecting this problem was two-fold.

First, it was designed to showcase some of the misconceptions that they, as teachers, hold about measures of center. As can be seen from the NAEP item in Figure 1, this question requires participants to think beyond the formal mathematical definition of mean and median, and assess the appropriateness of each measure of center within a given set of data, a statistical task. Many participants began the session believing, incorrectly, that the mean was always the best measure of center for a set of data. Although they had taught the definition of median, they had never thought about when it would be used. This problem allowed for that discussion to unfold.

The table below shows the daily attendance at two movie theaters for 5 days and the mean (average) and the median attendance.

	Theater A	**Theater B**
Day 1	100	72
Day 2	87	97
Day 3	90	70
Day 4	10	71
Day 5	91	100
Mean (average)	75.6	82
Median	90	72

(a) Which statistic, the mean or the median, would you use to describe the typical daily attendance for the 5 days at Theater A? Justify your answer.

(b) Which statistic, the mean or the median, would you use to describe the typical daily attendance for the 5 days at Theater B? Justify your answer.

Figure 1. Measures of Center Engage Activity

Secondly, the problem was housed within a larger journal article that they read after identifying and discussing their solutions. This article became the foundation for the work that we completed that day (Zawojewski and Shaughnessy, 2000).

The majority of each session was designed to allow participants to experience a variety of activities and discussions to deepen their pedagogical content knowledge of the day's topics. Many times these activities were enhanced using technology and were connected to articles that were provided to participants for review on their own. A sample activity used during one session is described below.

Sample Activity: Box Plots (Jordan vs. James)

The question of the best NBA basketball player of all time is one that can be heard on sports radio stations across the country on any given day, and it usually comes to a heated battle between two players: Michael Jordan and Lebron James. Even those who do not consider themselves to be basketball fans express passionate views about one player or the other. For this activity, participants were asked participants to think about and discuss this question from a statistical viewpoint. Each group was presented with data on each player, which can be seen in Figure 2.

	A	B	C	D	E	F	G	H	I	J	K
1	**Field Goal Percentage**			**Average Points Per Game**			**Average Rebounds Per Game**			**Average Assists Per Game**	
2	Michael Jordan	Lebron James		Michael Jordan	Lebron James		Michael Jordan	Lebron James		Michael Jordan	Lebron James
3	52	42		28.2	20.9		6.5	5.5		5.9	5.9
4	46	47		22.7	27.2		3.6	7.4		2.9	7.2
5	48	48		37.1	31.4		5.2	7.0		4.6	6.6
6	54	48		35.0	27.3		5.5	6.7		5.9	6.0
7	54	48		32.5	30.0		8.0	7.9		8.0	7.2
8	53	49		33.6	28.4		6.9	7.6		6.3	7.2
9	54	50		31.5	29.7		6.0	7.3		5.5	8.6
10	52	51		30.1	26.7		6.4	7.5		6.1	7.0
11	50	53		32.6	27.1		6.7	7.9		5.5	6.2
12	41	57		26.9	26.8		6.9	8.0		5.3	7.3
13	50			30.4			6.6			4.3	
14	49			29.6			5.9			4.3	
15	47			28.7			5.8			3.5	
16	42			22.9			5.7			5.2	
17	45			20.0			6.1			3.8	

Figure 2. Jordan vs. James Data File

They were then charged with the task of using only this data to answer the question, "Who is the better basketball player: Michael Jordan or Lebron James?" The emphasis in this task was on the interpretation of box plots, and participants were introduced to an online box plot creation tool (Box Plot Grapher: http://www.imathas.com/stattools/boxplot.html). This tool (Figure 3) allows users to enter a five-number summary for up to three data sets, and it then creates the corresponding box plots. This tool was selected for use with the teachers in order to focus their attention on the interpretation of the box plots, a statistical task, and not the creation of them.

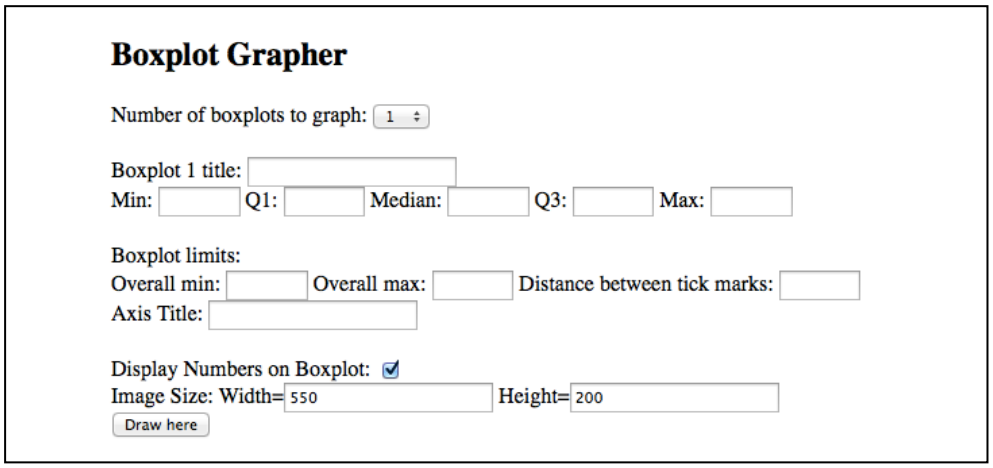

Figure 3. Box Plot Grapher: http://www.imathas.com/stattools/boxplot.html

This activity allowed the participants to utilize both mathematical knowledge, in the calculation of the five number summary, and statistical knowledge in the selection of what data to plot and interpretation of the plots (Groth, 2007). Participants discussed enthusiastically whether points, rebounds or assists were the most important factor in determining the quality of a player. Many looked at several factors and compared the results. The follow-up discussion allowed each group to make their case and discuss how they had used the given data. This activity gives participants the opportunity, through a real life context, to understand the importance of the distribution of data, and is helpful in transitioning discussions from measures of center to measures of spread.

At the end of each session, participants returned to where they had begun by writing reflections on how their understanding of the day's topic had changed as a result of participation in the session. Participants were often surprised by how much they learned in such a short amount of time, and were excited about the prospect of using these new ideas in their classrooms. Details of these reflections are discussed in the next section.

SESSION OUTCOMES

The goal of this professional development program was to positively affect the attitudes and improve the pedagogical content knowledge of the participating teachers in the area of statistics. The *Survey of Attitudes Towards Statistics* (SATS; Schau et. al, 1995) was used to measures how participant attitudes towards statistics changed after participating in this program, and teacher journal entries and results on the *Learning Mathematics for Teaching* assessment (LMT; Hill & Ball, 2004) were used to determine changes in pedagogical content knowledge.

Teacher Attitudes: Value and Affect

The SATS was administered at the beginning of the first session and end of the final session to the 14 participants. This assessment measures a subject's attitudes towards statistics within six domains: effort, cognitive confidence, value, difficulty, interest and affect. Although participants completed the entire survey, for this paper, only the results related to value and affect are reported.

On the SATS, there are nine questions related to value. Value is defined as how much a person understands the usefulness of a topic, in this case statistics. In order to analyze the change in value, the median scores for each of the nine questions for both the pre and posttest were summed for a total value score. The median values for both the pre and posttest as well as the totals can be found in Table 1. A Wilcoxon signed-rank test showed that the statistics professional development did elicit a statistically significant change in participant value scores ($Z = -2.87$, $p = 0.0021$).

Table 1. Median Pre and Post Scores on Questions Related to Value (n=14)

Item #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
Pre	6	4	5.5	5	5	4	5	6	5.5	**47**
Post	6	5.5	6	6	6	5	5.5	7	6	**52.5**

There are 6 questions related to affect on the SATS. Affect is defined as the feelings a person holds about a topic, in this case statistics. The median affect for each question on both the pre and posttest as well as the totals can be found in Table 2. Although the median total affect score increased (1 point) between the pre and posttest, it was not enough of a change to result in a statistically significant increase ($Z = -1.45$, $p = .0735$).

Table 2. Median Pre and Post Scores on Questions Related to Affect (n=14)

Item #	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
Pre	**4**	**4**	**5**	**4**	**4**	**4**	**27.5**
Post	**6**	**5**	**4**	**4**	**5**	**5**	**28.5**

Pedagogical Content Knowledge

In order to measure changes in pedagogical content knowledge, two methods were used. The first was the *Learning Mathematics for Teaching* assessment designed to "elicit both teachers' common and specialized knowledge of content" (Hill & Ball, 2004, p. 337). The data, probability and statistics assessment used with participants contains thirty-five questions related to content taught in grades 4-8. This assessment was given prior to the first session and after completion of the last session. On the pretest, the mean score was 52% or 18.33 ($s = 4.97$) out of a possible 35 points. The highest score was 29 points (83%) and the lowest was 12 (34%). On the post test, the mean score was 61% or 21.43 ($s = 3.89$). The highest score was 30 points (86%) and the lowest was 16 (46%).

The second measure used to assess a change in pedagogical content knowledge was teacher journal reflections. As mentioned previously, participants were asked to complete reflections at the end of each session. Participants repeatedly shared their excitement over gaining new knowledge or increasing their current knowledge. For example, one participant wrote, "I experienced some aha moments today. It was very refreshing to learn something new about a subject I thought I knew everything about. I know that I need to change my way of presenting mean, median and mode to my 5^{th} graders so that they can excel in the higher grades." While another wrote, "Wow! I really got a better understanding of what median and mode really mean. I learned what affects or how to change both the median and mean." Others shared specific examples of how their conceptual understanding had grown as a result of the day's workshop. One participant wrote, "Mean is more than the average of your data. It deals with the data set being equally distanced from the mean. Mean, mode, and median all deal with the middle of the data, just in different ways." The final theme in many of the daily reflections was an assessment of what they enjoyed about the day's workshops. They felt that the structure of the sessions was important in their success, "What I like most about today's professional development is our professor's ability to break down the information through discussion and questions to understanding of how it can be used in our classrooms."

CONCLUSION

We are living in an increasingly data driven society that requires its citizens to be able to manipulate and analyze large amounts of information. It is the job of our teachers to prepare students for that society. However, if they are not themselves adept at analyzing information, they cannot be expected to teach that skill set to the next generation. We must continue to find ways to engage teachers in the learning of statistics. As one teacher wrote in her journal, "It is not important for the data to prove the hypothesis, but just in the pursuit of gathering information the results add to our knowledge. This is an important truth that all students should understand." As the field of statistics education continues to grow, there is excitement about the continued improvement in the work being done with teachers, and especially watching how it affects student achievement in elementary and secondary education and beyond. The importance of this work is best summed up by a teacher's reflection of, "Today has truly been enlightening. I personally am grateful for a better way to teach my students this concept."

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