DIVERSITY AND DIFFERENTIATED INSTRUCTION AND LEARNING

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Instructors of statistics have struggled with the wide range of preparation of the students coming into statistics classes. This can include the mathematical preparation in secondary school for the introductory statistics course. This wide range of experience is complicated by the fact that different students have different learning styles. This paper will look at the idea of differentiated learning that allows students with weaker backgrounds to look at additional materials (through Web interfaces) to help fill in the gaps in their backgrounds so that they can be successful with the statistical content presented. Differentiated learning can also allow better students to go beyond the core statistical content to investigate more advanced topics (again on their own through Web interfaces). These differentiated learning experiences can be tailored to fit students' learning styles.

BACKGROUND

Over the past 15 years colleges and universities in the United States have experienced increasing enrollments even as the numbers of students enrolled in high school has leveled off or begun to decline, see Figure 1. In addition, colleges and universities have seen a slow, but steady, increase in the numbers of students from different ethnic backgrounds.

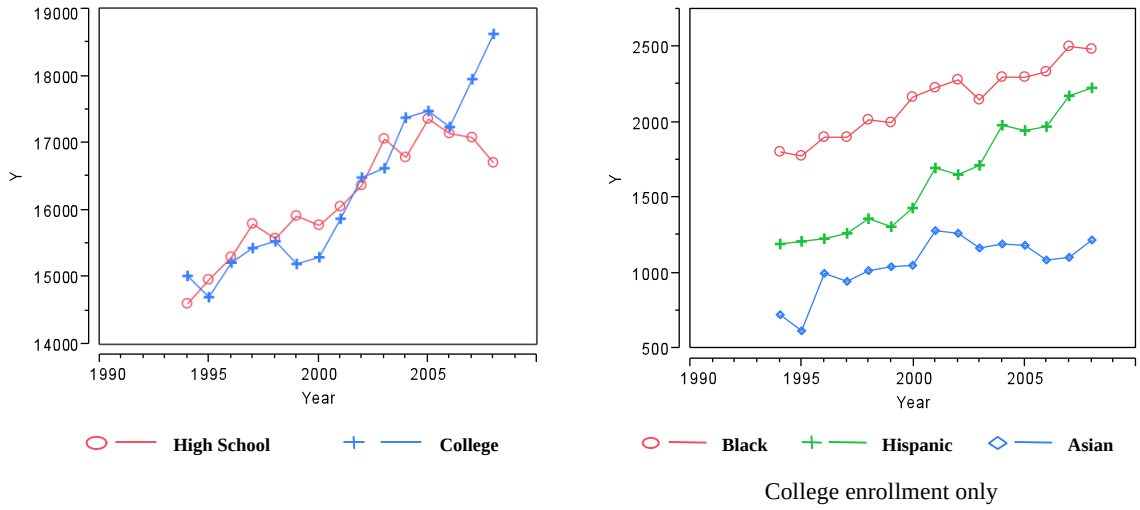

Figure 1. School Enrollment in the United States (Numbers in thousands).
Source: U.S. Census Bureau.

The changes in the demographics of who is pursuing a college education in the United States creates a new, interesting and challenging environment for statistics instructors. Introductory statistics classes have been taken by a broad spectrum of students in terms of mathematics preparation and interest in statistics. Today and in the future statistics instructors are facing and will be faced with an even more diverse set of students in terms of age, ethnicity and cultural backgrounds.

How should statistics instructors reach out to all students so that each can learn and be successful in a statistics course? This paper will offer several suggestions on how to address the diversity in preparation for the introductory statistics course and the diversity in learning styles of students. To do so, the paper will briefly review Gardner's (1983) theory of multiple intelligences. Data will be presented on the relationship between measures of these intelligences and performance in an introductory statistics class. General recommendations will be made on how to incorporate multiple learning styles in the presentation of statistical content. Specific activities will

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be discussed that incorporate different learning styles. Two of these activities can be used to differentiate the learning experiences of students in an introductory statistics class.

LEARNING STYLES – MULTIPLE INTELLIGENCES

Traditionally human thought was considered to be a single process. Intelligence was the ability to learn and apply knowledge. Additionally, an individual's intelligence could be described in terms of a single, quantifiable construct. That construct could be measured by means of an Intelligence Quotient (IQ) test. Gardner (1983) took a broader view of intelligence to include the ability to solve problems, to generate new problems or to offer something of value within one's culture. Based on this broader definition of intelligence Gardner devised seven distinct categories, multiple intelligences, to explain different aspects of intelligence and how different people learn. Brief descriptions of Gardner's intelligences, paraphrased from Silver, Strong and Perini (2000), are given below.

Verbal-Linguistic Intelligence (VL): This is the intelligence associated with language. People with a strong verbal-linguistic intelligence are good at manipulating words. They enjoy reading and often read for hours at a time. They tend to learn more when they are able to read, write, listen or speak about a subject.

Logical-Mathematical Intelligence (LM): This intelligence forms the foundation of scientific thought. People who have a strong logical-mathematical intelligence are good at seeing relationships and finding patterns. They tend to be rational and are good at critical thinking.

Spatial Intelligence (S): The ability to recognize and make images and pictures corresponds to spatial intelligence. Individuals with spatial intelligence remember things visually. They often learn by using graphs, tables, diagrams or images to organize words and ideas.

Musical Intelligence (M): The ability to appreciate and produce music, melody and rhythm forms and individual's musical intelligence. People who are able to keep tempo, play a musical instrument or sing in key exhibit musical intelligence.

Bodily-Kinesthetic Intelligence (BK): This intelligence involves bodily movement and the physical self. Individuals with strong bodily-kinesthetic intelligence are often good athletes. They tend to learn better through activities involving movement and doing.

Interpersonal Intelligence (P): This intelligence forms the foundation of social behavior. People with strong interpersonal intelligence tend to work well with others. They do well in team or group activities and learn better when they can relate to others.

Intrapersonal Intelligence (I): This intelligence involves self knowledge. People with strong intrapersonal intelligence tend to work better on their own as they are attuned to their own strengths and weaknesses.

Gardner (1999a, 1999b) examined other potential categories for new intelligences. This examination led to the inclusion of an eighth intelligence, Naturalist Intelligence (N). A person with a strong naturalist intelligence is attuned to the surrounding natural environment. They are good at classifying and categorizing natural objects.

Unlike the traditional view that sees intelligence as unitary and unchangeable; multiple intelligences are variable and can change over time. A particular intelligence can be strengthened through practice or weakened through lack of use. Students come into a statistics class with an intelligence profile – strengths and weaknesses among the seven, or eight, multiple intelligences. How variable are these strengths and weaknesses and do strengths or weaknesses in certain intelligences relate to performance in an introductory statistics class?

MULTIPLE INTELLIGENCES AND PERFORMANCE IN INTRODUCTORY STATISTICS

In order to look at multiple intelligences and performance, students in an introductory statistics class during fall 2009 were asked to participate in a research study. Forty one students agreed to participate. The introductory statistics class is taken by students whose majors are in the agricultural and biological sciences. The students were asked to fill out questionnaires assessing their strengths in terms of the multiple intelligences categories. At the end of the semester, information on performance in the class; exam, quiz, homework, lab and project scores were also collected.

There are many different instruments for identifying an individual's strongest intelligences. The two chosen for this preliminary study are a 35 statement True/False instrument by Piper (2002) and an instrument involving 32 statements each with a 5-option Likert-like scale. This latter instrument will be referred to as the Find Your Strengths instrument, a longer (56 statement) electronic version of which can be found at the literacyworks.org website; http://literacyworks.org/mi/assessment/findyourstrengths.html.

Each of the instruments consists of a series of statements. Different statements are related to different intelligences and all intelligences have multiple statements. Some sample statements taken from Piper (2002), with the associated intelligence, are reproduced in Table 1.

Table 1. Sample statements from Piper (2002) Multiple Intelligence Quiz

Statement	Intelligence
It's easy for me to say what I think in an argument or debate.	VL
I can add or multiply easily in my head.	LM
I'd rather draw a map than give someone verbal directions.	S
I can play (or used to play) a musical instrument.	M
My sense of balance and coordination is good.	BK
I like to gather together groups of people for parties or special events.	P
If I am angry or happy, I usually know exactly why.	I

The instructions for Piper's (2002) version are to mark T if the statement sounds true for the most part, F if it sounds false for the most part and leave it blank if the statement is sometimes true and sometimes false. Strong ability in a given intelligence is indicated by answering T to 80% or more of the statements associated with that intelligence. Table 2 gives the eight intelligences (note that none of Piper's statements addressed the Naturalist intelligence) and the number of students who would be classified as having strength in that intelligence using Piper's instrument. The instructions for the Find Your Strengths instrument are to evaluate each statement using a 5-option Likert-like scale where 1 = Statement does not describe you at all and 5 = Statement describes you exactly. Strengths were identified as the three intelligences with the highest average score. Alternatively, one could define strength as any intelligence with an average score of 4 or higher. According to this latter definition, the numbers of students who would be classified as having strength in that intelligence are given in Table 2.

Table 2. Numbers of students exhibiting strength in an intelligence (n=41)

Intelligence	Piper Strength	Find Your Strength Strength
VL	10	8
LM	12	4
S	7	13
M	17	11
BK	14	18
P	23	16
I	14	19
N	**	22

Of the 41 students who agreed to participate in the research study, all 41 completed both instruments. The numbers of students displayed in Table 2 add up to many more than 41 because most students displayed strengths in several intelligences. It is interesting to note that the two instruments identified strengths differently. This could be due to question wording in the instruments. More students are identified as having strengths in Logical-Mathematical (LM), Musical (M) and Interpersonal (P) intelligences using the Piper instrument. Using the Find Your Strength instrument more students are identified as having strengths in Spatial (S), Bodily-Kinesthetic (BK) and Intrapersonal (I) intelligences. Not surprisingly, over half the students were

identified as having strength in the Naturalist (N) intelligence. Recall that this introductory statistics class is taken by students with majors in the agricultural and biological sciences. Regardless of which instrument is used, relatively few students were identified as having strength in the Logical-Mathematical (LM) intelligence. Many more students were identified as having strength in, for example, the Interpersonal Intelligence (P).

In order to look at the relationship between multiple intelligences and performance, performance in the introductory statistics course was quantified as the cumulative score on all exams, homework assignments and quizzes. The multiple intelligences were quantified differently for the two different instruments. For the Piper instrument, answers were given numerical values: T = 1, F = 0 and if a statement was left blank a value of ½ was assigned. The total of the numerical values for the statements associated with a particular intelligence became the score for that intelligence. Scores for the intelligences went from 0 to 5. For the Find Your Strengths instrument, the average Likert-like scale score was used to numerically quantify the intelligences. Stepwise regression was used to identify potential relationships between intelligences scores and performance in the statistics course. The results are summarized in Table 3.

Table 3. Relationships between multiple intelligences and performance

	Piper		Find Your Strengths	
Term	Estimate	P-value	Estimate	P-value
Intercept	263.0		240.0	
Verbal-Linguistic	9.6	0.0240	16.9	0.0173
Logical-Mathematical	14.2	0.0024	14.6	0.0433
RSquare	0.295		0.246	
RMSE	39.1		40.4	
Number	41		41	

Not surprisingly, performance in an introductory statistics class was related to the degree of strength in the Logical-Mathematical intelligence. Additionally, the Verbal-Linguistic intelligence added significantly to the predictive power of the Logical-Mathematical intelligence. The amount of variation in performance explained by the intelligences is relatively small (25% to 30%). Still, there is some evidence that strengthening students Logical-Mathematical intelligence can contribute to better performance in the introductory statistics class.

Note also that performance was quantified in terms of the ability of individual students to solve homework problems, take quizzes and tests. All of these assessments rely heavily on Verbal-Linguistic skills. Additionally, the content of many homework, quiz and test problems in an introductory statistics course are Logical-Mathematical in nature.

GENERAL RECOMMENDATIONS

Once instructors are aware of students' multiple intelligences there are several things that can be done to create a learning environment that is rich in the use of multiple intelligences. In my own classroom I tend to use activities and presentations that focus on Verbal-Linguistic (VL), Logical-Mathematical (LM) and Spatial (S) intelligences. Perhaps this is because these are the intelligences that I have strength in. As instructors we often model intelligences that have led us to success in hopes that students will be able to strengthen these intelligences. The challenge is to come up with activities and presentations that tap into the students' strengths. Table 4 presents general activities that are associated with Gardner's original seven multiple intelligences. I believe that most of us can come up with examples from our own classrooms for many of these intelligences but is there a fair distribution of activities or do certain activities, and thus intelligences, dominate?

Table 4. Activities associated with the multiple intelligences

Intelligence	Activities
Verbal-Linguistic	Listening, reading, writing, discussions.
Logical-Mathematical	Calculations, conducting experiments, making inferences and comparisons, describing relationships.
Spatial	Visualization, visual presentations, videos, concept maps.
Bodily-Kinesthetic	Use of manipulatives, hands-on activities and demonstrations.
Musical	Playing or listening to music.
Interpersonal	Group activities, cooperative learning, peer tutoring.
Intrapersonal	Self evaluation, reflection, independent study.

It is not only the presentation of content but the method of assessment that has an impact on learning. Virtually all assessment, especially in large lecture courses, requires Verbal-Linguistic skills. Much of the assessment of knowledge of statistical content requires Logical-Mathematical skills. If this is how we assess then we must strive to not only tap into the intelligences students have strengths in but to strengthen intelligences that are important in the assessment process. Alternatively, we could think of ways to assess statistical knowledge that allow students to draw on different intelligences.

SPECIFIC ACTIVITIES

Below are descriptions of three sample activities that present statistical or prerequisite mathematical content. The activities are discussed in terms of the intelligences that are used. Hopefully these sample activities will spark an interest in creating additional activities and assessments that can tap into students' multiple intelligences.

Sample Activity 1: Algebra Review

The usual prerequisite for an introductory statistics course is 1 to 2 years of high school algebra. At the beginning of the semester we administer an algebra review assessment covering basic algebraic skills including solving equations for an unknown and working with linear equations. Many students have difficulty with this review assessment primarily because they have not used algebra for several years. With increasing numbers of older students enrolling in college, this time lag between when students are first exposed to algebra and when they use it in an introductory course in statistics becomes even longer. These students need to refresh their memories on basic algebra skills.

The web site http://www.algebasics.com/ provides instruction and practice on all aspects of basic algebra. There are sixteen sections and each section has several demonstrations. For example, Section 11 on Linear Equations has demonstrations on graphing straight lines, working with and finding the slope, and writing the equations of lines. Each of the demonstrations is very visual (Spatial Intelligence). The instruction is self paced and every student can focus on those aspects of algebra that are his/her weakest (Intrapersonal Intelligence). Each demonstration has an audio explanation that the student listens to (Verbal-Linguistic Intelligence) as she/he views the demonstration.

Sample Activity 2: Experiencing Variation

A fundamental concept in an introductory statistics class is variation; how to recognize variation, how to display and quantify variation and how to explain why variation exists. During the first week, have students fill out a questionnaire as a means of collecting data on the class that can be used throughout the semester. One question should ask for the student's height, in inches. When numerical variables are discussed, rather than simply display the data on students' heights, have the students participate in the following group activity (Interpersonal Intelligence). Have all the students stand up (Bodily-Kinesthetic Intelligence) and ask if everyone in the class is the same height. By simply looking around it is clear that there is variability in heights. Ask the students to group themselves according to height; at least 50 but less than 55 inches, at least 55 but less than 60, etc. and to line up from shortest to tallest within each height group. Have the students count off

to find the middle one (if there are an odd number of students) or two (if there are an even number of students) students. Write down the height(s) of the middle student(s). The students are now divided into two halves, the taller students go to one side of the room and the shorter students to the other side of the room. Ask if the students notice anything about the makeup of the two halves. It doesn't take long for someone to notice that there are a larger proportion of males among the taller students and a larger proportion of females among the shorter students. After this the students go back to their seats and the instructor can begin looking at the numerical data on the heights of students in the class. When the instructor goes through the stem and leaf with the numbers the students have the visual image (Spatial Intelligence) of the students in groups and lined up from shortest to tallest. This visual image can then be related to the visual representation of the distribution of heights given by a histogram. The histogram of students' heights is often bi-modal and the students realize that gender could be the explanation for that characteristic shape. The activity taps into students' Spatial, Bodily-Kinesthetic and Interpersonal intelligences that can be associated with the manipulation of numbers. Hopefully these associations will help strengthen the Verbal-Linguistic and Logical-Mathematical intelligences needed to organize, display and quantify the numerical values, heights of students.

Sample Activity 3: The Effect of Bin Widths on the Shape of a Histogram

This activity extends a homework assignment in which students find a data set consisting of at least 25 observations of a numerical variable. The homework assignment requires the use of a statistical software program, JMP, to display and quantify the variation in the observations. JMP automatically chooses bin widths for the histogram. Those students wanting to go beyond the required part of the assignment are given instructions on various ways the bins can be changed in JMP. The students must manipulate the bins (Bodily-Kinesthetic Intelligence) so as to create two histograms that give different visual impressions (Spatial Intelligence) of the shape of the distribution. They are also asked to notice how changing the histogram bins affects the box plot. Finally, they are asked to write a paragraph (Verbal-Linguistic Intelligence) about how and why changing the bins affects the histogram and the box plot (Logical-Mathematical Intelligence.

CONCLUSION

Given the current diversity of students and the prospect of even more diversity in the future, it is important that statistics educators try to tap into students' strengths when presenting statistical content. Statistics educators can also offer differentiated opportunities for students to improve prerequisite mathematics knowledge or go beyond the standard content. By creating activities that utilize several intelligences, perhaps more students will be able to learn and be successful in our introductory statistics courses.

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