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Improving Quantitative Reasoning Through Analysis of News Stories

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Abstract: Most universities in the United States require undergraduates to take a course in mathematics, but students take these classes with great reluctance, even though it is clear that quantitative analytical skills are becoming more valued in our complex society. A novel way of both sharpening students' analytic skills and emphasizing their importance will be the focus of a new course "Communicating Quantitative Information".This presentation will discuss the inspiration, institutional context, justification, and first experiences for this course, which satisfies the State University of New York State general education requirement for mathematics/quantitative reasoning. Students will study topics presented in news stories. For example, students will study the use of percentages, comparisons, and context through an article titled "More women than men murdered on the job". In both the headline and the story, the writer compared percentages of percentages to reach an inaccurate conclusion. Similarly, students will be introduced to statistical concepts such as measures of centrality, norms, mean, median, and variance through stories on "Educational high stakes testing"; dimensions of data, comparison and context is approached using "Pre-Challenger shuttle flight data"; and probabilities and correlations are addressed using topics such as "AIDS testing", "Friendly Fire", "Smoking risks" and "Hormone Replacement Therapy".Students will quickly find that such stories often are published with significant errors of interpretation or omission of critical information. This will provide opportunities for classroom discussion, and encourage students to develop analytic skills that prevent them from being misled by sloppy numeric interpretation. The classroom experience is supplemented by required participation in an on-line forum in which students post questions and critiques about current items in the news. Students gain experiences using spreadsheet, graphing, and general and specialized search tools in a computer classroom. The use of actual stories and topics provides a direct, authentic approach to the task of providing students with basic skills and understandings as well as serving the goal of preparing students for civic engagement, knowing the world in order to change the world.

Keywords: Mathematical Literacy, Innumeracy, Authentic Education, Mathematics Education

Introduction

PURCHASE COLLEGE/SUNY, ALONG with many colleges in the United States, requires students to demonstrate what is termed proficiency in mathematics and, afterwards, take an additional course that has been designated as teaching quantitative reasoning. This is part of the general education / distribution requirements that define what is meant by a liberal arts college degree. The proficiency standard can be met by adequate scores on standardized tests, taking a test administered at the College or taking a course titled Intermediate Mathematics. The content is mainly algebra, with some geometry and trigonometry. The quantitative reasoning courses include pre-calculus, calculus, several statistics courses, logic, programming courses, and a course in the history of mathematics. Unfortunately, many students, typically 40% to 50%, reach the College still needing to satisfy the proficiency standard. Especially for those students, the quantitative reasoning course is perceived to be an additional burden. This is especially true for students in the humanities, who do not have to take mathematics courses as part of the requirements for the major.

While many students are reluctant to take courses outside their major, mathematics courses appear to invoke higher levels of anxiety than the courses in history, sociology, science and writing according to private communications from their advisors, our colleagues in other disciplines. This is consistent with frequently reported news stories of students in the United States ranking far down the list on international tests in mathematics. For example, the Programme for International Student Assessment (PISA) study, conducted every three years, ranked the United States 24th out of 29 countries in the Organization for Economic Cooperation and Development, a Paris-based group that represents the world's richest countries (OECD, 2003). Students from Finland and South Korea scored best in the survey, which measured the ability of 15-year-olds to solve real-life math problems.

Students who arrive at college with weak skills in mathematics try to avoid talking more mathematics courses. Moreover, the problem with mathematics appears to have an emotional and motivational

component as demonstrated by the research on math anxiety (Hannula, et al. 2004, Tobias, 1991).

While acknowledging that the problems of avoidance of mathematics and lack of skills in mathematics may be particularly acute in the United States and the existence of general education or distribution requirements is not universal, we hope the experience and the course described here is of general interest.

Addressing Student Motivation

In spite of the strong acceptance of technology by college students and the historical importance of mathematics, many students work hard to avoid mathematics courses. Any attempt to change this situation would need to involve strategies relating to motivation and attitude.

Our goal was to create a new course, with substantial mathematics content, that would appeal to reluctant students. The new course, called "Communicating Quantitative Information," would use information and data presented in news stories for study and analysis. Thus, the course is aimed directly at quantitative reasoning to serve the practicalities of civic engagement. The faculty view preparing students to become engaged citizens one of the missions of the College. To this end, the administration agreed to a program in which newspapers are delivered to the dorms and student centers. Being able to understand important issues is part of being an engaged citizen. The proposed course pleased faculty members outside of mathematics, which meant that students would be advised to take the course.

One wonders how many readers understand news stories with quantitative content given the reportedly low-level of mathematical skills of the general public. In addition, such news articles may have errors of commission or omission. This last phenomenon was and still is viewed as providing pedagogical benefit for the course. The fact that a story is badly done can be intriguing for students and give them the patience and motivation to try to understand the material and to attempt to do a better job at communication.

To sum up, it was felt that learning mathematical topics in the context of use, that is, the authentic use of understanding the critical issues of the day, would be conducive to teaching and learning. This is consistent with the goals and theory of constructivist education. Knowledge is built by action on the part of the student, not just absorbed (Wheatley, 1991). Similarly, the motivation of needing to know the news issues, along with the group experience, would put learners into what is termed the 'zone of proximal development' (Vigotsky, 1962) where learning can best occur.

The course also came about because of the interests of a professor, the first author of this paper, who as an avid consumer and critic of "the news" and made the observation that news stories involving quantitative information and quantitative analysis are commonplace. For example, the issue of changing the United States Social Security system was very much in the news prior to and during the first running of this course.

Course Content and Structure

The course is a standard in-class lecture/discussion, twice a week, supplemented by required and optional participation in on-line discussion forums. Three class sessions are held in a computer classroom. Because of the use of the computer classroom and, also, because the instructor wanted a small group, the class was capped at 26 students (two students dropped the course mid-way into the semester).

The grade allocation for the course is the following:

Original Blackboard postings on news stories	15
Responses to other postings	10
Spreadsheet and graphing exercises	10
Project I: story re-write	10
Midterm	10
Project II: story re-write or interview report	15
Class room exercises	10
Final	20

Students were required to make at least three original online postings describing a news story that uses quantitative information. In this context, 'original' means that only one student can cite a specific story in a specific paper. These postings were to contain a summary and a critique. It was acceptable, even desirable, to write that something was missing or unclear. That is, the students were not required to solve any problems. In addition, students were required to respond to other student's postings.

The projects each required an initial posting of a proposal for the project, namely the topic and if the

project was individual or a two-person team; a presentation; and a paper (3-4 pages, standard bibliography, graphs). The teams were required to produce more in terms of quality and quantity (4 pages instead of 3 pages, multiple graphs, and deeper analysis).

Instruction was given on the use of Excel to make spreadsheets and charts.

Lecture charts and guides for the midterm and final quizzes can be viewed on the website indicated in the Bibliography. A sample test question is:

Pick 1:

- A poll is taken of 2030 registered voters in NYS asking their opinion (pro or con) of Governor Pataki. The results were 42% favorable. Calculate the margin of error (show expression) to make a statement with 99% confidence (z-score factor is 2.58, compared to 1.96 for 95% confidence).
- Determine and explain if the margin of error gets larger or smaller as a) size of sample goes up and b) the test proportion gets farther from .5. Explain the relationship of the confidence factor and the margin of error.

The topics included the three described next along with measures of centrality (examples from educational testing and housing prices), election polling, chance to win the lottery, HIV testing and false positives, map projections (the so-called Greenland problem), digital images, the decision to launch the Challenger, Social Security, medical insurance, mortgage rates, and sports records. Here are more details on three topics.

More Women than men Murdered on the Job

Over a dozen years ago, a newspaper published an article with the headline, "More women than men murdered on the job". The article was quickly identified as a case study in incorrect quantitative reasoning. The facts were the following:

- People die 'on the job'.
- Of the people who die 'on the job' for the specific past year, 93% are men and 7% are women.
- Of the men who die 'on the job', 15% are murdered.
- Of the women who die 'on the job', 40% are murdered.

The writer of the article and the person who composed the headline each compared the 15 to the 40 to reach the conclusion that women were more vulnerable than men to being murdered on the job. The writer posed the theory that this may be because women have jobs such as late shift nurses and waitresses and, generally, are weak and subject to attacks.

This is the example featured in the first day of the course. In the class, the students are asked to estimate (quickly) the number of men and women who died on the job, based on the assumption that 6000 people in total died on the job that year and then estimate the number of men and women murdered. They are then asked to do the calculations. The tricky nature of comparing percentages of percentages becomes clear, along with practice in estimation. The 40% of 7% is much less than 15% of 93%. The story had a significant error of omission (what is killing the men?) as well as the faulty conclusion.

The students are not good at either estimating or calculating. It is hoped that the experiences provided in the class of doing estimations and calculations would improve their skills.

The students did engage in discussion on the topic. The teacher asked: what is the definition of 'on the job'. For example, one issue that emerged was whether or not the murder rate included traffic accidents while commuting. There also is the question of "what is murder?" One student made the comment that the jobs probably were limited to legal occupations and that the omission of prostitution may have had a significant effect on the proportions. The teacher responded that this was insightful, but it probably would have been the case that illegal activity by males was at least as prevalent and dangerous as illegal activity by females.

The general lessons of this example related to calculations, fractions and percentages, definitions, and omitted information.

Housing Prices and Everyone to take the PSAT

A common new story is a report on home sales. Frequently, the news articles contain a correct reference to a mathematical concept, namely reporting the median as well as the mean and often even including the comment that the median may be a more appropriate measure.

Reports on how well students do on national tests are very common news stories. The first author related a personal experience concerning testing. Many years ago, the decision was made by the administration at the local high school to encourage all juniors to think about going to college by making everyone take the PSAT test by scheduling it during school time and paying all the fees. This decision was reported at a small meeting which the first author attended along with some other parents. The first author said [something like] "that is a very nice thing to do and I am all for it, but you do realize that scores will go down." Most of the people at the meeting expressed surprise and disagreement with this prediction.

These two 'stories' served as motivating examples for what are termed measures of centrality and the notion of distribution. Here is a brief review of these basic statistical concepts.

Given a set of numbers, the mean (also termed the average) is calculated by adding the numbers up and dividing by the numbers in the set. The median is a number with the property that half the numbers in the set are greater or equal to it and half the numbers are less than or equal to it. The median is computed as follows:

The numbers are sorted into order, low to high.

- If there is an even number of numbers in the set, the median is the average of the two numbers in the middle.
- If there are an odd number of numbers in the set, the median is the one in the middle.

A number is a mode of a set of numbers if it occurs the most time. Since there can be two or more numbers that occur the same number of times, there may not be a unique mode.

Given a set of numbers, such as house prices or test scores, the distribution is expressed by a bar graph in which the horizontal axis holds the values and the vertical, the number of instances of each value. It also is common to group the values into ranges. If and when the size of the set of values increases, the graph is drawn as a continuous line, that is, not a bar graph.

The range of the set is either expressed as an interval: the value of the lowest number and the value of the highest number or it can refer to the highest number minus the lowest. The variance of a set of numbers is another measure of how the numbers are spread out. It is calculated by

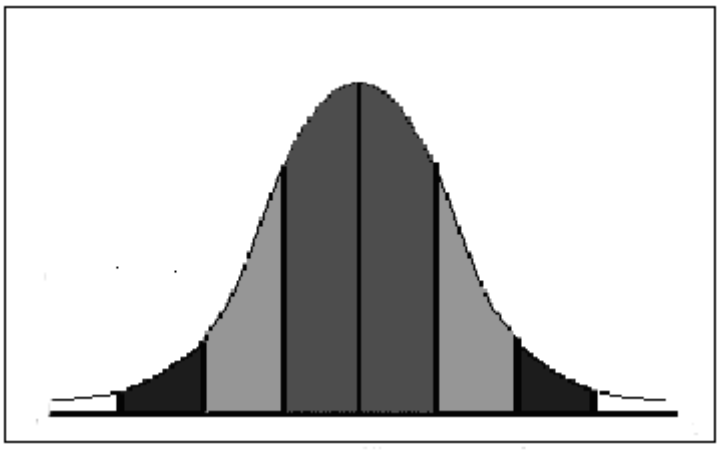
1. squaring the difference of each number with the mean,
2. adding all these values up,
3. dividing by the size of the set. This yields the variance.
4. The standard deviation is the square root of the variance.

As a formula,

Variance = $(\Sigma(xi\text{-}m)2)/n)$

The distribution shows how the numbers diverge from the mean; the variance and the standard deviation express the size of this divergence by a single number. If all the values in the set are clumped together, the variance and the standard deviation are low. If the numbers are spread out, the variance and the standard deviation are high.

Certain distributions have names. A uniform distribution is one in which all the values occur the same number of times: each of the bars in the bar graph is the same height. A normal distribution is what occurs for many phenomena in nature, such as heights and weights of large sets of people, or even, frequently, but not always, test scores and house sales. In the normal distribution, the mean, median and mode are all the same, and 68% of the set is within 1 standard deviation of the mean, the two middle mid-gray segments in the graph below; 95% are within 2 standard deviations, the middle plus the light gray segments, and 99% are within 3 standard deviations. The instances outside these segments are called the tails or the outliers.



In class, the students were led through many exercises involving these concepts. For example, using checkers to represent money, we showed that if you recorded what you spent for meals each day over several days and computed the mean, you spent the same amount of money as spending the mean each day. We computed means, medians and modes different ways. We observed how the mean, median and mode changed when adding a specific number. This was made [more] meaningful to the students by asking, if your grades in a class were

- 30, 66, 78, 90 (mean is 66)

and you made 70 on the next project, would the mean go up or down or stay the same?

Returning to the house sale story, suppose one month the sales were 300000, 350000, 410000, 420000, 550000, 600000, and 660000. The mean is 470000 and median is 420000. Suppose there was an additional sale for $3 million! The new mean is 786250 and the new median is 485000. For the typical home buyer, the median better conveys the selling price of houses.

The 'everyone to take the PSAT' story requires understanding of the situation and does make some assumptions. The first author made her prediction based on the notion that the new students being pulled into the pool of PSAT test takers would not be, for the most part, the better students. They mainly would be from the low end, perhaps even from the lower tail/outlier. This would have the effect of bringing down the mean and the median and broadening the range.

One other common distribution is called bimodal. This consists of two normal distributions next to each other. The teacher made the remark that if some students prepared for the midterm by using the preparation guide and some students did not, the results would be bimodal.

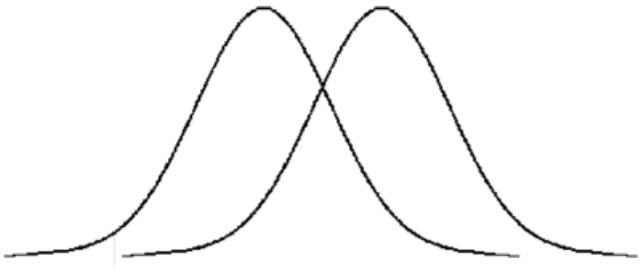
What the President of Harvard said

It was our hope that news events, and the resulting published articles, would occur that would be appropriate for classroom discussion and the controversy over what Larry Summers, president of Harvard University, said were the reasons for the small proportion of women in science and mathematics at Harvard was ideal. Dr. Summers' comments and follow-up reactions were covered heavily in newspapers, radio and television. The relevance of the story to the class was not Summers' conjecture regarding women in science but that his explanation was framed in terms of a statistical quantity. Summers' statements concerned what is termed the tails of the distribution of innate abilities to 'do science'. He suggested that the variance of men's abilities is greater than the variance of women's abilities. That is, there are more very smart and very stupid men! His claim was more subtle (though still highly debatable) than most people originally believed. The following is from a transcript (Summers, 2005) of the remarks made available after the event:

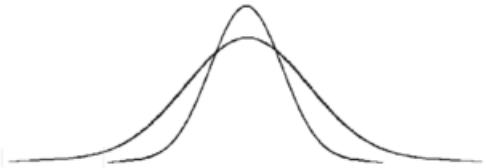
> So my sense is that the unfortunate truth-I would far prefer to believe something else, because it would be easier to address what is surely a serious social problem if something else were true-is that the combination of the high-powered job hypothesis and the differing variances probably explains a fair amount of this problem.

After the lessons on measures of centrality (mean, mode and median) and then distributions, including the normal distribution, students were asked to draw curves representing what Summers said. The following is a sampling of what the students produced.

a.



b.



c.

Initially, most students made drawings similar to a. and b. and not to c, the correct representation. The follow-on lecture and discussion made the students appreciate the distinct concepts involved. The critical mathematical lesson concerned the concept of distribution and size of the tails of a normal distribution. These students felt a great sense of accomplishment in coming to an understanding of a topic more sophisticated than most of their peers could grasp. This example illustrates the motivation for creating the course: real world examples promote learning.

First Experience

The first experience with the class was strongly positive, in terms of the experiences of the teacher and students and in student performance. The evidence of positive experience by the students is through comments made to other faculty, such as "I never thought I could do this" and "These are things I need to know" and an end-of-course anonymous survey. It is our plan to engage in more systematic research during the next offering of the course.

The class reached its cap very quickly. Because of the way registration is done at the college with students registering according to the number of credits accumulated, the course was practically all seniors. This meant that even though these students could be characterized as people who put off taking a mathematics class for as long as possible and who had not had formal instruction in mathematics since high school or since they took the course satisfying the proficiency, they were fairly savvy about being students. This trait outweighed the specific problems with mathematics. They knew the importance of understanding the grade distribution, completing assignments, and taking advantage of office hours, preparation guides for the exams, and study sessions. They also, again, for the most part, were willing to ask questions in class, including admitting that they did not understand something. The typical first or second year student may not have these skills.

The students, again, for the most part, quickly took to participating in the on-line discussion groups and most students exceeded the required quota of postings. The news topics chosen for postings included military recruiting, health issues, charitable giving, the issue of the music business and downloading, sports records, sports event attendance, crime rates, and so on. The spelling and grammar tends to be horrible and the thinking naïve. However, the postings often demonstrate idealism and interest. In these situations, there always is the question of how and when the instructor should participate. The following is a reply posting on an article on a UN program to vaccinate for measles:

> It's scary to think that the UN knows about this vaccine and it only costs .30 but will not offer it to all and especially in the unknown countries that most likely need it most. I wonder if what they say is true about having the disease become obsolete one day. I also wonder if in the USA if there are more cases reported depending on where ones live. On that same note I wonder what poorer countries out of the unknown have higher rates of disease then others.

Three students were really incensed that the UN planned to only vaccinate 90% of the children in a region in the developing world. The author/teacher did participate with 3 postings, the third being:

> Please bring this up in class for discussion.
>
> My reading of the article is that the estimate of cost is 30 cents to get 90% of the children.
>
> The cost would go up if that was an effort to track down everyone. This is not to say that it shouldn't be done, but the remarks about the cost may not be accurate. The 30 cents covers the cost of the drug itself and the procedures.

Another on-line discussion concerned a charitable contribution made by Wal-Mart. The first posting was:

> Recently Wal-Mart has donated 35 million dollars to the National Fish and wildlife Foundation. The donations will all together help to protect over 2 million acres of natural habitats. "It helps demonstrate the economic growth and development can go hand in hand with conservation," said Sarah Clark, a spokeswoman for Wal-Mart, the nation's largest company. Wal-Mart's donations may seem quite noble but it is no coincidence that they announced this donation only a week after environmentalists joined organized labor, and com-

> munity groups to attack Wal-Mart for its business practices. It just goes to show you; sometimes the only way to do good to pin evil against the wall

This was followed by two more analytical responses:

> Did the article talk about how much 35 million dollars is out of its total revenues? Because 35 million may look big on paper, and to most of the public that have never even seen 100,000 dollars, but to Wal Mart it might just be chump change to buy off critics of their business practices.
>
> I think this article, according to what you wrote, is a simple example of the importance of context. Context is not only important when dealing with numbers and their significance, but it is also important to understanding events and the development of one's opinion in response to these events. For example, I became very interested in Walmart's donation after it was placed in the context of time, after reading that Walmart's donation to the wildlife foundation was preceded by public criticism of the company by environmentalists. Similar circumstances surround fast food companies. I am reminded of an article I read that correlated the availability of healthier choices at McDonald's to the increased number of law suits against the company.

A final response from yet another student was:

> I'm out of the loop. What was wrong with Walmart's business practices?

It should be noted that on-line discussion provides documentation that generally does not occur for classroom discussions and, therefore, has considerable value for reflection on the course. These two examples are representative of most of the on-line and in-class conversations. Students were engaged and the discussions brought them into what is the 'zone of proximal development' in which teaching and learning can occur.

The students, even the history, journalism and political science majors, are woefully ignorant of current events and background information. They did not know that a gay person could be discharged from the United States military. They did not realize that the most common health problems of someone in the USA are different from that of people in the developing world. They did not understand how the current Social Security system works or the basics of mortgages, health insurance, stocks and bonds. This lamentable situation proved positive for the course. The students were interested in the material and felt that it was important and worth the time. The discussions dealt with both quantitative and general issues.

There were negative responses to the course, though it is unclear how to react to each one. The students, after the sessions on the Social Security reform issue, were directed to find a retirement calculator and either use it for themselves, do it with or for a parent, or make up information. They were instructed to report generally on the experience and NOT divulge any personal or family financial information. Most of the students reported that this assignment was very interesting and worthwhile. However, a couple of students said that it was intrusive. One suggested that the instructor post information for several dummy cases and allow them to do the assignment with this data. A couple of students 'did not like Excel'; several students expressed appreciation for the chance to learn Excel. Students do not like giving presentations, but most agree that it is appropriate.

An on-line post-course, anonymous survey, taken by only 9 out of the 24 students indicated mostly positive experiences. The survey included three 'essay' questions:

- What do you like about the course?
- What would you change?
- How would you describe the course to others?

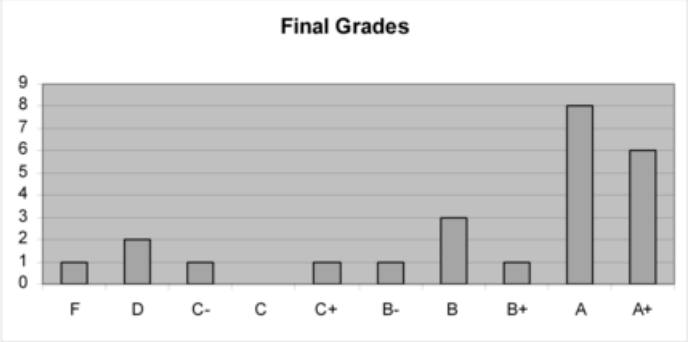
These questions have served the teacher/author well in the past for providing qualitative information about the course.

- Samples from the positive responses
  - I enjoyed how the class related to REAL life information. And how you gave us cookies to relate to the number of calories in the first excel lab. -Any time you gave out food.
  - I most enjoyed the topics that related to my future, such as mortgages and health insurance. These were very useful! The simulations (with the dice and coins) were very engaging and informative. I would like to have done even more of them! Also, if it weren't for this class, I probably never would have learned to use Excel. The cookie lab was superb!
  - I liked using various newspaper publications as a part of the course documents because I am a journalism major.
  - I liked the format of the course and i can't really think of anything that i would change. i wasn't a big fan of the postings but it is a important part of the course and it gets the students to read the news paper.
- The one negative response

- The lesson plan didn't really make sense, it seemed like we were just learning a bunch of random things that didn't have much to do with each other or anything.

A quantitative question was also asked: express agreement, neutrality or disagreement with the statement After taking this course, I feel more confident than I felt before in understanding news stories involving quantitative information (including detecting situations in which there is missing or mis-leading information). This yielded 77.7% agreement. Again, keep in mind that the N for this study was only 9.

The performance of the students, that is, the grades earned, was outstanding as shown in this graph:



The bottom end of the distribution should be increased by 2 for the 2 drop-outs.

A joke was made by the teacher prior to the midterm and then again prior to the final: that there would be a bimodal distribution if some students studied, using the preparation guides, and some did not. In fact, there was not a bimodal distribution either time.

Two sections of the course are scheduled for Spring, 2006 and they each reached their enrollment caps in the first couple days of registration. This is an indication that 'word on the street' is positive.

Conclusions and Future Directions

The course is aimed at mathematical literacy, also called numeracy. It does not fit into any classical mathematics course. The objective is to raise the skill level of quantitative reasoning, not provide instruction in formal mathematics. The use of actual stories and topics provides a direct, authentic approach to the task of providing students with basic skills and understandings as well as serving the goal of preparing students for civic engagement, knowing the world in order to change the world.

Using a topics approach does mean that the course can be viewed as disjointed. The teachers must help the students make connections between topics and stress general principles, such as definition of terms and putting things in context.

The course does need tweaking. For example, the open notes policy for the midterm and the final quizzes will be changed to allowing the students to prepare a couple pages of notes. I anticipate that this will help the weaker students, who 'hear' open notes, and then do not study but bring all the lecture notes to the exams. The process of condensing the important information into a small amount of space, that is, figuring out what is critical and what is not, is a form of studying.

It is planned that more careful pre- and post-surveys will be done in order to better understand the effects of the course. This could include obtaining contact information for the students to do a follow-up study on their consumption of news at a point-in-time after the course. In particular, we plan to use one or two of the scales for Math Anxiety, for example, the MAS (Pajares, 2005) on a pre- and post-basis or the Survey of Attitudes Towards Statistics, SATS (Schau, 2005).

Another strategy is to investigate how students 'self-identify' themselves as 'math person', 'science person', 'humanities person', or 'artist', and so on and what this means. If the student did not identify as a 'math-person', the testing instrument would ask the student to pick the statement that corresponds most closely with their beliefs:

1. I could be more of a math person if I took courses or paid better attention in class or took the time to investigate those topics.
2. I could never be more of a math person even if I took the time.

The same question would be asked for the other classifications. This instrument could be given to a cohort of first year students and a cohort of seniors and not limited to those taking the course.

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