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## 1. Today's Mathematics Students

A common mistake that undergraduate mathematics professors make when teaching is to assume that students are younger versions of themselves. Since many mathematics professors are above average in intelligence and were quite good students, the assumption that students are just like themselves can cause pedagogical difficulties (Krantz, 1993). To teach effectively, it is important to understand students. Yet, understanding today's students is literally like bridging a generation gap (Hawk, 2005).

Studying generation gaps is, perhaps, unfamiliar territory to mathematics educators. In mathematics, one counterexample proves a theorem false, but in making generalizations about generations of mathematics students, one does not examine individual cases. In fact, any individual may have none of the described characteristics (and yet be a member of a given generation) and most individuals will not have all the characteristics. In fact, it is possible that variation within a generation is greater than variation between generations. Yet, sociologists do attempt to describe generations by providing a variety of information, which could prove useful to educators.

Such information might lead educators to understand their students' culture and, thus, the influences on their students, even if such influence is manifested to a more or less degree in individual students. Sociologists attempt to describe the motivations, interests, personalities, and other traits of a generation by describing the so-called "personality of the cohort." For example, Neil Howe and William Strauss (authors of Millenials Rising: The Next Great Generation, 2000) define generations as "a cohort group whose length approximates the span or a phase of life and whose boundaries are fixed by peer personality" (Howe & Strauss, 1991, p. 60). Further, the peer personality is defined as a "generational persona recognized and determined by (1) common age location; (2) common beliefs and behavior; and (3) perceived membership in a common generation" (Howe & Strauss, 1991, p. 64). It is possible, then, to distinguish one generation of students from another.

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**2. A New Generation**

The generation of people born between 1980 and 2000 are called the "Millennial" generation and many of the earlier born are in college now. In fact, the term Millennial originated because the earlier born entered college in 2000 and the last born will enter college in 2020 (Franklin, 2005). Sociologists claim that Millennials are different from Baby Boomers (born between 1946 and 1964) and Generation X-ers (born in the 60s and 70s). Millennials are confident, hopeful, goal- and achievement-oriented, civic-minded, impatient, and inclusive (Raines, 2000). While Generation X-ers are certainly used to television and probably personal computers, the Millennials in college now came of age while immersed in the Internet and email. Of course, the Baby Boomers were not brought up on the computer at all. Consider the following dates.

- The World Wide Web was invented in 1989-1991.
- The DVD was invented in 1995 (the VCR was invented in 1971).
- The Apple Macintosh was invented in 1984.
- The Windows program was invented in 1985.
- The TI graphing calculator was introduced in 1990 (the very first graphing calculators were invented around 1985).
- Ebay began in 1995, as did Amazon.
- What professors consider new, today's college students have lived with for a majority of their lives.

**3. Mathematics Background**

Perhaps even more important than understanding the cultural differences between today's college professors and today's college students is understanding the mathematics background of today's college students. Based on the fact that more students take remedial mathematics courses than ever before, students are entering college with different mathematics, such as less algebra (Levine & Cureton, 1998). According to a national survey in 2000, approximately 75% of mathematics teachers agree with the principles of the National Council of Teachers and Mathematics (NCTM) and implement them to at least a moderate degree (Horizon Research, 2002). It is important to understand, then, what the principles of the NCTM are. Roughly, the NCTM calls for less attention to procedural understanding and by-hand-symbol manipulation, and more attention to problem solving, conceptual understanding, and technology use.

Yet, based on standardized test results it appears that mathematical skills are either the same or improved. The national average ACT math score has been about the same from 1995 through 2005 (available from ACT, http://www.act.org). The national average SAT score is up 14 points since 1995 (available from SAT, http://www.sat.org). NAEP scores are up since 1995 (available from the National Center for Education Statistics, http://nces.ed.gov/nationsreportcard/).

How can we reconcile decreasing college mathematics placement scores and increasing standardized mathematics test scores? One possible answer is that these two sets of instruments measure different skills. Certainly increasing scores on standardized tests is encouraging. However, college mathematics placement tests consist of numerous algebra manipulation problems. These type of problems are virtually absent from standardized tests such as the ACT and SAT.

In sum, incoming students have fewer algebra skills than previous generations of students. Of course, one might argue that more students enter college than in previous generations. Some studies suggest that incoming freshmen have more general problem-solving skills, and increased knowledge of statistics and data analysis (Senk & Thompson, 2003). Students are savvier with all kinds of technology than previous generations were (Noeth & Volkov, 2004). There is even some evidence that students have better attitudes towards mathematics than previous generations did (Senk & Thompson, 2003).

**4. The College Experience**

Once in college, today's students have a different experience than most college professors had when they were students. For example, in 1973, only 36% of all full-time college students were employed, but by 1995, the percent was at 69 (Hansen, 1998). In 1999, the percent of full-time college students who were also employed was an astonishing 80% (Oblinger, 2003). Bluntly, parents no longer pay for college (Levin & Cureton, 1998).

While living on campus is on the decline, drug and alcohol use are on the rise among college students, as is binge drinking and casual sex (Levin & Cureton, 1998). In addition, today's college students have the most severe psychological problems of any generation of college students (Kitzrow, 2003). Obesity, asthma, and attention-deficit disorder are also on the rise (Howe & Strauss, 2000).

During class, students have shorter attention spans than they once did, and they often try to multitask, even during lecture. Today's students spend time (when they could be studying) surfing the net. Obviously, this was not an issue for yesterday's students. My own university (a medium-sized Midwest university) conducted a survey via email in 2005 of all 642 students with a major in science, mathematics, or engineering, and 189 replied (a response rate of approximately 29%). When asked what gets in the way of their academic performance (students could check off as many items as they desired from a list of items, including “other”), 32% checked the answer "surfing the web,” which was the third most popular response. The first most popular response was procrastination (65%) and the second most popular response was "social activity" (36%). However, only 16% said "partying." By the way, "loneliness" was also rather high at 29%. "Playing computer games" came in at 28%.

**5. Implications**

If we are convinced that current students have a significantly different background, both culturally and educationally, and have a different college experience than current professors, one is left wondering what should be done with this knowledge. Some researchers suggest that current students need certain pedagogy in place in order to learn (Carlson, 2005; Frand, 2000; Levine & Cureton, 1998; Oblinger, 2003). Current students need to:

- be engaged in the learning process and not sit passively taking notes (Carlson, 2005).
- have a say in what happens in the classroom (Frand, 2000).
- be treated like the customer (Oblinger, 2003).
- In addition, current students cannot tolerate delays of any kind and they want to be doing rather than knowing (Frand, 2000).

In practical terms, this could take the form of structuring one's classes so that students work in groups, learning by trial and error (or one might say "discovery learning"). Technology, such as graphing calculators, would be a vital part of one's courses. And, the professor's role would be one of facilitator and giver of feedback.

These are, of course, radical changes in the normal lecture format of college mathematics classrooms. One must consider, however, if the radical changes in college students do not, in fact, demand such radical changes. Yet, one also has to consider if all of this is more theory than reality. For example, if we asked Millennial students who are undergraduate mathematics majors how they want their mathematics courses taught and what they think of technology, what would they say?

**6. A Survey**

In 2006, an email survey was conducted at my own university. Recall that it is a university in the Midwest. It is the second largest university in the state, with a reputation as a solid university. The university is both a teaching and research university, granting bachelor and master degrees in most disciplines, but no doctorates are granted. The Mathematics Department is a large service department, as engineering degrees, along with science degrees, are extremely popular at the university. Also, at any given time, there are approximately 100 students majoring in mathematics. The Mathematics Department made a decision in 2000 to attempt to ease the transition of incoming mathematics students from high school to college mathematics courses. One idea the department formed was to have cooperative learning in small groups in some (but not all) of the mathematics classes.

To form the sample for the email survey, the researcher began with a list of all mathematics majors (again, approximately 100), and eliminated those students who were born earlier than the definition of Millennial allows. The researcher then eliminated students who had not experienced at least one mathematics course taught in a traditional lecture format and one mathematics course that included small groups. Although this does not eliminate all possible bias (e.g., perhaps the professors who teach one type of class are somehow better than the professors who teach another type of class), it at least makes it possible to state that the students in the survey had experienced both types of learning. This left 63 students in the sample. The survey consisted of two open-ended questions:

1. In your mathematics classes, do you prefer listening to a lecture, working in small groups, or something else (if something else, what)?
2. What is your opinion about the use of calculators in mathematics classes?

Twenty-eight students replied (a response rate of approximately 44%). Twenty-five (or 89%) said that they definitely preferred lectures, with the remaining three (11%) students saying they wanted a combination of lecture and small groups. Nobody preferred small groups to lectures and nobody suggested another alternative. However, all the students put qualifications on how the lectures should be. Consider the following three quotes:

*I personally enjoy a lecture as long as the instructor uses good in-class examples on how to solve the problems that we are expected to know how to solve on homework and tests.*

*I prefer lecture, if it is well prepared and there is time for questions.*

*Personally, I just like lectures for math but one thing that professors should do more of is examples*

So the Millennial students at one university (or at least those who felt strongly enough about it to answer the email) like lectures. However, the lectures that they like are a tad bit different from the traditional definition of lecture. The following statement may be the best summary: "I prefer listening to a professor lecture with some class involvement in the lecture" [italics added]. It is not acceptable to students that a professor simply stands in front of a class and talks. The professor should be aware of the needs of the class. The lecture format is fine with students, but the professor should include examples and take questions. The professor should be aware of the class enough that he or she adjusts the pace of the lecture accordingly. The professor can still take the role of a leader, but she or he must try to help the students during the lecture with what the students will actually be doing. However, many of the Millennial mathematics majors do not want to "use up" classtime working with classmates in small groups.

Only one student mentioned that the professor might consider using technology, such as PowerPoint. Still, even that student said it should be "every so often" as a supplement to the chalk/chalkboard approach, just for "variety". One student mentioned that professors should photocopy their handwritten notes for students to use during class (not a very technology savvy approach at all!). This last suggestion was for pacing reasons, as professors were accused by most students as going too fast during lecture. Consider this quote, "I think professors forget that we haven't been doing this for 10+ years and we need time to catch on."

The students who preferred lectures viewed small group discussions as either a waste of time (because mathematics is best learned individually) or something that one could easily facilitate on one's own. And even students who preferred a mixture of lecture and small group discussion thought that the small group discussions needed to be carefully monitored by the professors.
I don't like to spend long periods of time in class working with the group because most students procrastinate and waste the time. For in-class groups I think it's better to do only simple problems that can be completed in less than 3 minutes. [This student preferred both lecture and small groups.]

It's easy to set up small groups to study for classes, and I think that helps students clarify any material they may be confused with. [This student preferred only lecture during class time.]
I like to work in small groups when doing homework. It's kind of like getting the best of both worlds. [This student preferred only lecture during class time.]

The calculator question was asked to help ascertain students' perspective on technology use. The answers showed more variation than the answers to the lecture question. In the Mathematics Department, some courses are taught with graphing calculators required, and some courses are taught with graphing calculators banned. However, a previous survey of all the majors revealed to us that almost all students (99%) own a graphing calculator and made considerable use of it in high school. Returning to our current survey, 16 (or 57%) students supported calculator use; eight (29%) supported no calculator use; and the remaining four (14%) felt neutral about the issue. Those that supported calculator use tended to support the use of a calculator in all things, at all times. The justification for this philosophy was that it is a technological world and school prepares one for the world. Consider this representative quote:
*I believe that school should be viewed as preparation for the "real world" and in the "real world" your boss wouldn't ask you to solve a problem without a calculator!*

However, there was also the group of students who did not like calculators.

*I hate being dependent on a calculator.*

*Calculators are rather pointless, since you need to show all of your work.*

*There are so may different things that a calculator can do which takes away what the student should be able to do (i.e., derivatives, integration, standard deviation, combination, permutation).*

*I'm against calculators, as any good math student should be.*

*My opinion on calculator use is that it is really abused in the classroom.*

*I have found them nearly useless.*

One interesting response discussed that if "professors really got to know every student they would be able to build a level of trust and respect that would prevent the students from using functions that are not allowed." This student is saying that there may be functions on the calculator that the professor does not want students to use. Regardless, that professor should have such a close relationship with his or her students, that if he or she says, "don't touch that button", it is guaranteed that students won't. That is an amazing level of closeness, much beyond what is the norm in the past. Calculators are viewed by some of the Millennial students as simply a part of life and therefore should be a part of the classroom. However, this is not the case with all the Millennial students. Thus, it is not the case that all Millennial students need technology use in order to see the worth of a course of study.

The results of this small survey support the idea Millennial students desire their mathematics professors be aware of them and their needs. In return, the Millennial students offer their respect and attentiveness (to a well-prepared lecture, for example). However, the absolute need to work in groups or be submerged in technology was not supported in this survey.

**7. Closing Statement**

Theorists suggest that the Millenials are very different students from previous students. Implications are that undergraduate mathematics professors ought to teach mathematics in a different format than for previous students. A survey at one Midwest institution revealed that students do not dislike the lecture format, per se, nor are all of the Millennials convinced that calculators are a must. Rather, these students want personal attention during the lecture. A mathematics professor, when lecturing, should try to use lots of examples, pace the lecture, have a relationship of trust with students, allow calculators to the degree that makes sense for a particular class (and even perhaps negotiate this with students), and, in general, should be checking with students on how it is all going. It is not less of a relationship that students want with professors, but more. Rather than exclusive use of small group discussion, these students want an "interactive lecture." Perhaps it is appropriate to end this paper with two sentences used earlier: These are, of course, radical changes in the normal lecture format of college mathematics classrooms. One must consider, however, if the radical changes in college students do not, in fact, demand such radical changes.

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