Teaching Algebra to a Diverse, High-Risk Student Population

at the

University of Houston - Downtown

Presented by

The Institute on Learning Technology

part of the

NISE: National Institute for Science Education

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Spring 2000

This case study also is available from the Learning Through Technology web site, www.wcer.wisc.edu/nise/c11/ilt.

Acknowledgements: The authors thank the UHD faculty, staff, and students who participated in this study. These individuals very graciously responded to our requests for their time and attention. This case study is based on a collaborative analysis and planning process undertaken by the NISE's Learning Through Technology "Fellows" group: Jean-Pierre Bayard, Stephen Erhmann, John Jungck, Flora McMartin, Susan Millar, and Marco Molinaro. The Fellows, in turn, benefited substantially from members of the College Level One Team: Andrew Beversdorf, Mark Connolly, Susan Daffinrud, Art Ellis, Kate Loftus-Fahl, and Robert Mathieu.
Summary

Key Practitioners: Professors William Waller, Linda Becerra, and Ongard Sirisaengtaksin

The University of Houston-Downtown (UHD) is a 4-year urban University with a commuter and ethnically diverse student population. Located in downtown Houston, this University provides educational services to non-traditional students, many of whom are under-prepared and work full-time.

In the past, students learned mathematics by simply becoming familiar with manipulations and calculations required in course content. Fundamental concepts, as well as their relevance to real life problems were entirely ignored often by both students and faculty. As a result, students primarily saw mathematics as a requirement, which they must satisfy, in order to obtain a college degree. Students did not appreciate algebra's use and applicability to real-life situations. Even those skills that students supposedly learned in algebra courses, often had to be re-taught in later courses.

With this as a backdrop, 3 faculty members initiated reform in their college algebra course to solve 3 challenges:

- **Student performance**
  About 70% of the students across all course sections of Math 1301 (college algebra) were failing.

- **Student preparation**
  One of the key reformers said, "...Many of our students don't have a high level of academic success...they have had bad experiences with math...or hadn't enjoyed it..."

- **Traditional methods weren't working**
  They didn't see the content as very relevant...It's not fun for them, so we have all the ingredients of a disaster. The course was not technology oriented, so to them that just emphasized that it's irrelevant."

Specifically, the reformers were trying to:

- **Provide numerous opportunities to learn.**
  An important trademark of UHD is its commitment to help students succeed...
almost regardless of previous performances or failures.

- **Have their students learn fundamental concepts and skills through real-world problems.**
  
  *We wanted to make sure that the fundamental concepts and skills (and we thought a lot about what fundamental means) are emphasized.* and *"Again, give them the idea that mathematics is practical and meaningful to their lives and that they're capable of doing it a little bit, and understand why they're doing certain things."*

- **Stimulate interest by making mathematics relevant.**
  
  *The math content in this reformed course is presented as a solution to an engineering or other science field problem.*

- **Increase math literacy.**
  
  *As one reformer said, "We hope to just inform them of the possibilities."*

- **Learn diverse teaching strategies.**

- **A technology-dependent curriculum.**
  
  *As a reformer said, "We wanted to think about making the curriculum in such a way that it required the use of technology."*

To put all of this into context, we'll provide a brief description of the students, the faculty, and the Institution itself. We'll also describe specifically what the reformers did with the technology and what evidence they have that it worked!

**Ongard Sirisaengtaksin**

Finally, we'll describe how and why these faculty got started down this reform path, and the myriad of implementation issues they were faced with to make this all happen.

### The challenges to be solved

When a faculty member considers curriculum reform, there are usually problems or learning environment challenges that motivate that consideration. At UHD, with such a high course load, the disincentive for initiating reform is even greater. We found that there were 4 main reasons that led these three faculty members to initiate reform in their college algebra course. We address each reason, individually, in order of importance.
Student Performance

"We were unhappy with the results we were getting. The failure rates were very high..."

First, poor student performance is by far the dominating factor that inspired this group of faculty to consider reforming college algebra. 70% of students across all course sections of Math 1301 failed. Earlier, discussion of student population demographics explained how education is prioritized. UHD’s demographics and low expectations, which usually result from such an environment, probably played a role in the dismal performance recorded before reform. A faculty member reflects on these old unhappy days:

We were unhappy with the results we were getting. The failure rates were very high - some 24% passing rate (C or better passed). Actually we tallied this up about a year [before] we looked at our courses, specifically college algebra, before we started incorporating technology - so we looked at our sections to see what we had been doing. And it wasn't just one instructor or one book or any one characteristic that was having the high failure rates, it was uniform across the department no matter who was looked at, it was the same failure rate.

Students discouraged by failure caused low retention rates. In addition, students did not learn fundamental concepts they needed in order to succeed in more advanced courses. This provided faculty with a strong incentive to come up with a plan that would help students retain knowledge of algebra concepts beyond their final exam period. A faculty member explains:

The retention problem ties into the concepts that they didn't quite get it. For example the concept of a function, they should learn that in college algebra and they're supposed to be knowledgeable after they go from college algebra to calculus. We found out that a lot of students in calculus had no idea at all what a function is. They were not getting the concepts that were being taught. We were trying to use this technology somehow to either reinforce concepts or introduce them in such a way that it will stick into their mind. That's another reason why we use technology.

Student Preparation

Second, if student performance is the quintessential challenge that motivated reform in this college algebra course, then student preparation is right behind. In many instances, both faculty and administrators hail nontraditional aspects of their student population as a strength. While it is clear that the University has carved out a population niche that it serves, it also faces some daunting challenges in preparation and traditions of its incoming students. When asked why does he think students were failing so miserably, one algebra instructor answered:

That's the $64 question. Everything that we say here is pure speculation. Many of our students don't have a high level of academic success in the past. These are the reasons..."
that you hear people, not just us, but people give. They weren’t successful; they have had bad experiences with math in the past or hadn’t been successful in math in the past, or hadn’t enjoyed it. But they might have gone through an entire high school algebra sequence or close to the whole high school algebra sequence. So they had some algebra skills; they’d seen this stuff before, but hadn’t been successful with it before. And here we are in college and they’re getting it all—they’re going through the whole experience all over again, the same experience that they were unhappy with in high school. So it was like, deja vu all over again. The same material taught in exactly the same way but just at a faster pace.

At many institutions, students with this kind of prior learning experience are discounted. For these UHD algebra faculty reformers, these students represent a challenge, albeit one of significant proportion. One can even decipher a sense of pride in value-added education provided to students. These faculty members see their role as instrumental in both making up for missing knowledge, as well as imparting new knowledge to their students. UHD’s hallmark is to provide opportunities for success, as many faculty pointed out to us. Here is how one faculty member summed it up:

One of the challenges was to make sure that students succeed. And we’re very proud of our graduates. Sometimes it takes a lot of work to make sure that they’re able to absorb the knowledge. One of the reasons is that some of our students do not have the benefit of coming from the top high schools. So their background is not particularly strong. So one of our roles is to make sure that they are able to succeed. And in order to do that, we’ve got to provide the appropriate environment, which means, that we have to get them to fill out those gaps of their education so that they are able to compete.

Traditional Methods Weren’t Working
Third, several faculty members, including some other than algebra faculty, felt that traditional methods of teaching mathematics did not connect with students, particularly students who did not grow up in an environment with a college tradition. They felt that it was imperative to link mathematical content to students' everyday lives. Material and its relevance, making course content useful in students' eyes, became a theme that we frequently heard in investigating this case. Use of pen and paper, or blackboard and chalk added to students' impressions that course content was obsolete and passe. A faculty member reflects emotionally on that issue:

They didn't see the content as very relevant; even after our reform, they still don't see it as very relevant. I get this comment constantly that I don't see this is as very relevant to my career. It's not fun for them, so we have all the ingredients of a disaster. The course was not technology oriented, so to them that just emphasized that it's irrelevant. It was not taught in a very modern way, again, not connecting to their lives; the course didn't make much of an attempt at all to connect with their lives, just really in a rut, a course in a rut if there ever was one.

It was customary for students to consider an algebra course a miserable experience they had to go through in order to obtain a degree, but one that hopefully they will never have to repeat. Like the students who performed poorly in these traditional
courses, faculty dreaded these teaching assignments:

Well we as instructors were unhappy too with the type of course that it was. For many students it was a terminal course and they were leaving their last math course with a very poor experience, one that is not very applied to their everyday lives. They had questionable skills of being able to solve theoretical problems, which they needed if they were going to continue with their mathematics sequence of courses. On the other hand, if they were never going to see math again, they weren’t ever going to have to recall those skills. So we just didn’t view the course as being very valuable, whether they were going on, or terminating at that point; and both the instructor and the student seemed to be unhappy with the course.

Access
Fourth, at an institution such as UHD with its working student population, we expected "access" to figure prominently on a list of goals that faculty and administrators held. It was not. The only concern related to "access" faculty had, was the capability of the worldwide web to provide access at home to continually updated software at no cost to students. The choice of software platform was heavily based on providing students free access either through the web or by way of a free player as in the case of Mathwright.

Faculty's goals
The algebra reformers described what they wanted students to "get out of" their algebra course. Here is how one reformer described the goals,

Some of them are technology-oriented, be able to use a calculator or computer to plot a table of points. Some of them are strictly by-hand skills, be able to solve a quadratic equation, be able to solve a linear equation and a linear inequality; so it’s a mixture of hand and technology skills, and then understanding concepts. They need to understand the concept of a function; recognize when something is a function; when something's not a function; domain and range of a function; is this number in the range of this function? So some of our skill goals are very specific and others are a little bit more broad and general.

What follows is the other major focal points the reformers' had as gleaned from their interviews, the order of which does not indicate importance:
• provide numerous opportunities to learn
• learn fundamental concepts and skills through real-world problems
• stimulate student interest by making mathematics relevant to the students' life
• increase the mathematics literacy
• learn using diverse strategies
• have a technology-dependent curriculum.
Numerous Opportunities to Learn
An important trademark of UHD is its commitment to help students succeed almost regardless of previous performances or failures. Faculty are aware of classroom challenges they face, but that only reinforces ed their resolve. UHD prides itself openly on its ability and commitment to provide many learning opportunities to its students, whether it is remedial activities or college-level activities. Several instructors speak about this learning environment as an embodiment of the American dream, a place where everyone has an opportunity to learn. One instructor comments on UHD's philosophy:

> We have our 25th anniversary this year and the president's motto is "Twenty-five years of excellence, opportunity and diversity", and the key word there for us is opportunity. Even though our students are under-prepared, we want to over and over be providing them more opportunities that are optional that they can take advantage of to be successful students. So we have a tremendously active math lab that offers tutoring by faculty, lecturers and faculty who are not tenure-track. The lab has practice software, drill type software, and it is open during extensive hours all through the week.

People we talked to at UHD seem to realize that their efforts have not yet shown results they hope/d for, but they are determined to continue on and seem very willing to consider other options, particularly those relying on computer technology.

Learning Fundamental Concepts and Skills Through Real-world Problems
The tension between students learning concepts and being proficient with skills is alive at UHD. One goal is for students to thoroughly learn certain fundamental algebra concepts, such as functions. To that end, these reformers included a number of activities in the course content. Course depth/breadth was reduced to accommodate these new activities. On the other hand, they recognized that college algebra is also a skill-building course designed to prepare students for more advanced mathematics courses. The re-designed curriculum focused on important concepts and on a reduced set of skills faculty felt students must have to succeed in future mathematics courses. This strategy did not compromise quality since most advanced courses often had to subsequently re-teach those skills anyway. An instructor explains:

> We wanted to make sure that the fundamental concepts and skills (and we thought a lot about what fundamental means) are emphasized. We were trying to narrow the focus of the course. When our students went on, we wanted to be certain that they could use some small set of skills well. We really wanted to practice those a lot instead of making it a mile wide and an inch deep, which is the way content is traditionally designed in college algebra. You typically spend a little bit of time teaching them all these exotic types of equations that need to be solved, and all these different categories of functions. We were trying to get away from that so we would make sure that when they showed up in the applied calculus course, they could solve a quadratic equation confidently, and we wouldn't have to be re-teaching that skill.
While this reformed course had content and skills needed to enroll in more advanced courses, these reformers also wanted it to be useful for students taking their last course in mathematics. The reformers accomplish this by using problems drawn from everyday situations, as discussed later. Thus, this reformed algebra course was intended to show how mathematics could be both practical and meaningful to everyone's life:

We wanted to make sure that they came out with a positive experience from a rounded course, sort of a self-contained course. Even if they didn't go on to another course, it would be justified; they would understand the importance of the material. It wasn't just that we're going to teach you this skill because you're going to need this in calculus. I'm not going to tell you why it's important here, but you're going to need it later on. It is like a stand-alone course with closure. It is also a skill-building course, though; you can't completely get away from that. Again, give them the idea that mathematics is practical and meaningful to their lives and that they're capable of doing it a little bit, and understand why they're doing certain things. Those are some of the key goals there.

Stimulate Student Interest by Making Mathematics Relevant to Students' Lives

Clearly, interest on the students' part in mathematics at UHD was lacking. Students tend to place work and family obligations ahead of their educational goals. This academic environment must make a good case for educational services that it provides to these students. These algebra course reformers included real-life problems as a gateway to mathematics to stimulate interest and encourage participation.

Well when we first developed our proposal we said we did want our students to see relevant examples from the sciences and engineering. When you open the materials, you get a context to a problem, and then come the mathematics. We try to let our students experience that over and over.

Mathematical content in this reformed course is presented as a solution to a problem either from engineering or another science field. A major instructor goal is to provide practical context to the content:

I think we want students to have a positive mathematical experience, if you will, that mathematics can be related to their everyday lives. So we present problems that are somewhat whimsical, but if you dig beneath our storylines, they're actually relevant to their lives. It's not just, solve a quadratic equation, factor this, simplify that.

Literacy in Mathematics

College algebra is a service course taken by both math and non-math majors. For math majors the reformers knew that concepts and skills needed to be taught and retained, while for students in which this would be their last mathematics course, the reformers felt the course should provide them mathematics literacy. To this end, the students would be shown applications of math concepts in their lives so that they
generally would be more informed citizens as well as be more aware of current technologies. One of the reformers explains:

*For us, functions became the central theme of the college algebra course. We hoped that, by concentrating on functions and then doing variations on a theme, retention of skills and concepts is improved for the students who do go on to other math courses. For the students who terminate with that course, we hope that they can look back and say, 'Yes I did learn something that I can apply to my life.' We hope they are more knowledgeable, become more informed citizens, and that they don't just play with symbols and numbers that they'll never have to use again. They can look at technology in new ways of visually illuminating something, or seeing how technology can do a by-hand calculation that they weren't aware of. Symbolic manipulation to them is still completely new, they have no clue that computers can do some of those things. We hope to just inform them of the possibilities.*

**Learning Using Diverse Strategies**
With a challenging student population like that at UHD, instructors look for opportunities to diversify their teaching approach. Technology with its graphing tools offers one such opportunity according to a faculty colleague:

*So the reason I do this is I think maybe by having the students see the concept from different vantage points and different angles, then maybe that will sort of make them retain the concept; and also once they see it, the utility of the concept in different disciplines, that may also encourage them to learn the concept in the course.*

**A Technology-Dependent Curriculum**
It is interesting to note the reformers' view on technology use per se. According to them, computer technology is fundamental to their reform. Activities they intended to carry out could not be done without computers. A reformer explains how crucial technology is to this project:

*We wanted to think about making the curriculum in such a way that it required the use of technology. We wanted to make sure that the technology wasn't kind of a gismo that kind of got added onto the course; where essentially we would teach the course in a traditional way and then stop and say, "Oh, but look you can also graph this with a calculator". We wanted to make sure there's no way to teach the curriculum without having the technology.*

**The Institutional goals**
The institutional goals for using classroom technology is wide-ranging and don't always aligned with faculty goals. UHD's College of Sciences and Technology has made a substantial investment in computer-based technology, and it is important for instructors to understand the underlying reasons for this investment because it likely will affect workload, expectations, and productivity. The four main reasons for this investment garnered from interviews are:

- distance learning
- efficiency/productivity
- remedial education
- marketing.

**Distance Learning**
The drive to engage in distance learning is one of the most pervasive trends at educational institutions nationwide. With UHD being right in the middle of a large urban community, one can easily conjecture that campus leaders see clear potential financial benefits in providing educational services through television and the worldwide web. However, the faculty seem more interested in solving learning-based problems than augmenting a university’s market share. An administrator talks about this disconnect between the administration's goals and the faculty's use of technology:

*I think that the university’s idea is that they are going to get new students by going online. However, I think most of the stuff that’s been happening at just the individual level is to help the students that are taking classes from the particular faculty member.*

A faculty colleague emphasizes what he perceives to be UHD's institutional intent on using technology:

*You’ve got to use some technology, and they [the Institution] are heavy into distance learning. We offer a lot of courses via TV and online. Online, not much, maybe one or two courses, but around eighteen to twenty courses are offered on TV.*

UHD has a Technology Teaching and Learning Center (TTLC). The TTLC "supports faculty in their efforts to successfully use and understand many new technology tools and strategies at their command. We assist faculty in development and implementation of interactive technologies, which increase pedagogical effectiveness." Visiting the Center, one gets a clear impression of its importance to the University. Equipment is new and state of the art. A staff member comments on TTLC's role, and UHD's distance learning goals:

*I think that the TTLC is very strongly in support of distance learning things and on-line course development. And so, the administration sees that as a way of making what we have to offer, available to people outside, you know, downtown Houston. And so we do have distant sites, and that's something that TTLC is involved in. They also support us in developing and using WebCT, and things like that, to organize our course materials, put things on the web. They offer a lot of workshops to individual faculty members.*

**Efficiency and Productivity**
Another institutional goal for investing in technology is to increase faculty productivity and reduce costs. Many tasks traditionally performed by staff members have been
reallocated to faculty, as staff positions are discontinued. An administrator explains:

*I think the university may want the faculty to be responsible for doing more things than they had to do before. We have been cut in our budget. For instance, we had two secretaries in the department. When we lost one, they didn't re-fund the position; so faculty no longer have someone to do copying for them, typing for them, all those kinds of things. You've got the computer in your office so you have to do more of those things yourself now.*

### Remedial Education

One is that our mission may be different than a lot of Universities in that we are very diverse.

Analysis of demographics, especially pass/fail rates, brought serious attention to computer use for self-paced remedial education. As will be discussed later, many of UHD's students come with a poor pre-college preparation. UHD's ability to serve these under-prepared students is crucial to its survival since that is its niche. UHD is resolved to find ways to remedy their students' poor background in math, science and writing even if they determine that to be successful would necessitate a sizeable investment in infrastructure. A staff member provides some context:

One is that our mission may be different than a lot of Universities in that we are very diverse. We're a commuter institution, we have a lot of first generation college students and, especially in other departments, a lot of their computer resources go toward those remedial courses, introductory courses; the students are required to do a lot of lab time to support their skills in math and writing.

An obvious question relates to the success of these remedial programs. While a diverse student population exists at UHD (see the next section), ethnic composition of its graduates is disproportionately white. Based on early 1990's data, there is clearly more work to be done. Some faculty members feel that the University may be providing finances to solve these problems, but it is doing so with little imagination or creativity. Opening and staffing new labs or sections is not enough, as one faculty member explained:

*I think the remedial program and its success or failure in helping students graduate, this is a real mark that the university doesn’t want. I mean we try, but we don't serve our under-prepared population very imaginatively at the moment. It's important to provide them the opportunity, but in providing the opportunity you have a responsibility to really try to serve them imaginatively and creatively. It's not just opening up the sections, but trying to figure out ways to make these students successful, and it's really difficult.*
Marketing
Lastly, technology is used as a marketing tool to indicate a certain modernism in the University's equipment and work of its faculty. Classrooms and labs that are outfitted with latest computers and devices figure constantly on UHD's tour guide. A staff member who provides technology support to the faculty clarifies this:

I don't think that this investment in technology is public relations as much as it is marketing. I think there is a fair amount of marketing, because, you know, every time a foundation is visiting, they always call me up and say, "Will you have lunch with us?" But, I think, that's not why they invested the effort. I think it's so that if there's going to be a market in on-line courses, if it's a cost efficient way of delivering instructions, then let's do that.

While universities like UHD see on-line course delivery as an investment, which promises a future low cost/benefit ratio, one wonders about the reality of success of an institution such as UHD in an open environment, where competition is likely to come from resource-rich institutions like MIT, University of Illinois, etc.

Putting it in context: The Students

The University serves a very diverse nontraditional student population. There are students who are starting college for the first time, while others are starting college for a
The average age of the student population is 25 years old. For the last two years, UHD has been named the most ethnically diverse western US liberal arts institution, a distinction that reflects that the student body is a good representative of the community served: If one looks at Houston's eastern community, one finds that it is one-third Hispanic background, one-third Afro-American, and one-third traditional white. An administrator considers the student population's ethnic diversity an important strength because UHD is able to tap into the best resources of all three groups:

![Image of Student Ethnicity 1990-1994]

**Figure 2. Demographics of UHD by ethnicity from 1990-1994.**

Since we are so representative of the community, our students, as they grow in their learning ability, are able to capture the different characteristics of all these groups. So when they go into the working environment, they're fully competent in their ability to know what to expect, how to relate, and how people think. Clearly, each individual group thinks, acts, or behaves a little differently. So our students are exposed to a variety of ideas and backgrounds, which we view as a very important part of our educational process.

"Many of them have families and jobs, so college is something that they have to fit into their schedule."

There is general agreement from both faculty and administrators that the University serves a largely under-prepared student population who does not place college education at the top of their priority list. This realization is at the root of many University decisions involving technology use in teaching both university-level as well as a remedial curriculum. It is interesting to note that most faculty are not discouraged by, or ashamed of, the academic preparedness of their entering students. On the contrary, they see this as a challenge which validates the need for educational institutions and environments like UHD. A faculty member reflects on this:

*I think we serve a large portion of under-prepared students and also underrepresented students. A lot of these students are first generation college students, so their family may not...*
have any experience with going to school. To me I think that's our most important audience, although we also serve a lot of people who are working in the downtown area, and just are coming here to try to complete their degree at night, or whenever they can get off of their job. So most of our students work, and many of them work full-time, so they're not the traditional college students that you would see at a prestigious university like Wisconsin. College is not usually the first priority for them. Many of them have families and jobs, so college is something that they have to fit into their schedule. And they're under-prepared. They're not academically gifted students, or at least that doesn't show up in their records usually. We also have a large group of students who have been to other schools like A&M or Texas and for various reasons have flunked out. So we're kind of the second choice institution.

According to a faculty member, many students treat UHD as a "junior college" although there are no associate degrees granted. A significant proportion of these students do not go on with their studies and complete only a couple of years of college education. This coupled with the open enrollment at UHD can have detrimental effects on attitudes and expectations that students bring to class according to the faculty member:

*Because of the open admission policy of the University, it can occur to a student that day or the day before to attend, as registration is occurring. There's nothing to prevent that student from enrolling.*

Finally, those students who do graduate from the College of Sciences and Technology have followed basically two pathways. One is to go on with their studies at a graduate institution. For example graduates in science programs, like biology and chemistry, may go on to medical school. These students have been relatively successful. A second path is with graduates of computing and mathematical science programs who usually go into the work force.

**Putting it in context: The Faculty**

UHD's primary mission is teaching, and both faculty and administrators are in complete agreement on this priority. Here is one faculty's comment:

*I mean the primary mission of the school is teaching. Teaching is the stated mission of the school and I think that's the administration's emphasis. There's some faculty who, I don't want to say disagree, but have a different idea of our mission, a more typical research mission. But I think the administration's views are focused on teaching.*

An administrator concurs:

*To us, the primary focus is quality teaching, quality transmission of knowledge. If that component is not there, the faculty will not be promoted. The first question we ask is, how is the performance of the individual in his/her teaching activities? We also inaugurate scholarship, and I'd say, depending on whom you talk to, you may hear that it’s equally weighted. There are two necessary, but alone not sufficient conditions.*
There appears to be a small segment of UHD who wishes that the University leaned a bit more toward the research university model. However, high quality classroom teaching seems to be most important criterion in promotion and tenure decisions. Classroom performance is determined primarily by way of student evaluations. Like many other teaching universities, the importance of research or scholarship is immediately established after teaching. An administrator frames the issue this way,

*Well, I think we are still pushing teaching as the main thing. If you are not doing well in the classroom, you won’t be able to get tenure. But on the other hand, once one does that, we are requiring more and more that one has to do some kind of, it’s not called research yet, but it’s called creative activities. So you have to be involved in something professional, whether it be writing papers, giving talks, writing textbooks, something that shows that you are active and you’re contributing, and that you have the potential for continuing to do that.*

How crucial or important is scholarship in promotion and tenure processes depends on whom you ask. Administrators are mindful to portray faculty as current and productive, and faculty scholarship is framed in a way that involves the participation of students:

*We expect our faculty to show progress in scholarship. We define scholarship in a very broad sense, including, what is traditionally called research. We like to call it a scholarship, because to me it indicates a better definition of what we would expect individuals to do, which is, perhaps, a little broader than writing journal papers. It would indicate participating actively in self-development, continuing to develop through, for example, joint activities with students, the kind of activity that we encourage here. So to us, a faculty member sitting in his office working out new theorems, or developing new theories, or writing individual papers is not really what we want. We want activities with students. So, we do have a large number of professors in the computing and mathematical science department who are very, very active, and they’re active nationally; they publish textbooks and papers, but they have very strong interactions with students. The students are all required to complete a project in their senior year, and this is where much of interaction comes in.*

The importance of scholarship seems to be increasing though. The College now has a significant amount of external funding. Many investments in technology infrastructure come from externally funded projects. One wonders if in the future there will be clear pressures on faculty to obtain outside funding that this College has benefited so much from. An administrator proudly touts this accomplishment of the College:

*Four years ago, this institution had practically zero external funding...today it's running up to two million a year...*

Currently, a high/large teaching load, which faculty are responsible for, seems to keep scholarship expectations modest, as indicated by an administrator:
Well, if you are teaching a full load which is the twelve semester hours, I mean we’re fairly happy if for instance one is doing research, if you do a paper every year or every other year; that’s I think considered sufficient. I mean, we still think 12 hours is a heavy load.

With such a high teaching load, one wonders about the faculty's ability or willingness to engage in collegial activities, such as curriculum reform, departmental and college-level academic discussion, or governance. To further consider this, and to ponder what are the appropriate conditions for change at an educational institution like this one, one might ask how does the institution accommodate change and/or adjust to new ideas? Moreover, how is change received or tolerated by the faculty as a whole? Is there peer pressure to accept, adopt/adapt, or reject change? Here's how one administrator answered these questions:

One or two instructors could deviate from the standard way of teaching a course, as long as they let us know. They could experiment with something, and I've basically told them that if they find something that is really good and is working, then it's their responsibility to convince the rest of us to change. So, I think there's been the freedom that people feel like they can try things, but it's very difficult to get the department as a whole to switch over to something. I mean we can't even get the department as a whole to agree to use calculators in a particular class. There's some who say, students have got to be able to do it without the calculator; I won't use it.

An accommodating environment lets faculty make changes in their own courses. Beyond that, there does not seem to be a process which could be used to have an entire department or college adopt these reforms. It is incumbent upon reformers to convince their peers, one by one if necessary, to adopt their method. It should be noted that in the case of this college algebra course, its success in implementing reform might have been predicated by the fact that these three faculty members responsible for teaching the course work well together and advocate for a reform agenda.

Putting it in context: The Institution

The University of Houston-Downtown (UHD) is set up into four academic colleges. One college is an intake unit, which accepts freshman and transfer students called, the University College. The Natural Colleges encompass the other three academic colleges and each offer their own degrees: The College of Business; College of Humanities and Social Sciences; and College of Sciences and Technology. The algebra course of interest, Math 1301, is offered by the College of Sciences and Technology.
Overall university enrollment is a little bit over eight thousand with a target enrollment of around eighty-one to eighty-two hundred students. Approximately one third of all credit hours taken by these students are earned in the College of Sciences and Technology though it does not have its proportional share of majors. Approximately one-sixth of all majors are in the College of Sciences and Technology so a major function of this College is to provide service courses for other university programs, especially in mathematics.

The College of Sciences and Technology is composed of three academic units: The Computer and Mathematical Sciences Department, The Natural Sciences Department, and The Engineering Technology Department. It also houses The Center for Computational Sciences and Advanced Distributed Simulation (CCSDS), a research center charged with developing additional external support for the institution and for students. An administrator speaks of the CCSDS's success in supporting the University's teaching mission:

"This is an institution which is mainly a teaching institution. It's not a flagship university..."

A lot of the funding has been generated or comes from that center. This is an institution, which is mainly a teaching institution. It's not a flagship university, as they call them in Texas or wherever. The main emphasis is the discovery of knowledge. Our main emphasis is transmission of knowledge or teaching. Although we have a significant amount of research, the research that we do here is very much student focused. The research really lets students get involved.

The Department of Computer and Mathematical Sciences, home department for this college algebra course, has some twenty faculty, tenured and tenure-track. There are about twenty-five more part-time faculty members. A typical teaching load is 24 credit hours per year, but many faculty members teach two additional courses during the summer for extra pay. A Chairperson leads the Department while still carrying a heavy teaching load (6 courses per year). Here is how the current Chair sees his role in the University hierarchy:

I think the Chair is considered faculty by the upper level administration, and administration by the faculty.
An accurate count of students majoring in mathematics is difficult to obtain because many do not declare their major until they reach their senior year. Typically, about 35 to 40 math students graduate per year. In terms of technology, it is clear that the University is investing in both its infrastructure and its people. A staff member reflects that opinion:

*I sense that the administration is very committed to technology. We have a big teaching technology learning center and the people in staff there are very helpful. They have twenty/thirty labs on campus, computer labs that they support, many of which are for the math department.*

The university is increasingly participating in distance learning via television or online course delivery. Because of student population demographics (as we discuss next), the University is also trying to make use of asynchronous, self-paced materials in its remedial programs.

*To me, computer tools are learning tools. I would hope that we are using the better learning tools that are available today in that particular technology. I know that in all the courses, which we called remedial, there is a requirement that students follow certain tutorials using the Plato system. We do have a Plato Lab set up for them. The lab is open seven days a week, about 12 hours a day, and that is part of the learning process. So there is a lot of computer-related learning going on in the mathematics area. I do know that we have placed a significant proportion of resources in modernizing our equipment. We have a very nice simulation laboratory, and we have several laboratories where students have full access to a lot these tools. We have been fortunate in that the state has provided us with higher educational assistance funds or short for HEAF, which is the way the state of Texas allocates equipment funds.*

The need for computer-based remedial activities, like Plato, is exacerbated by Texas State law, which limits student enrollment in remedial hours.

**The Learning Environment**

The creation of the learning environment with the use of computer technology is necessary to understand successful reform efforts. In particular, we focused on activities that make up part of the reform strategy for this college algebra course. In doing so, we consider opinions of a close faculty collaborator in this segment and in later segments. This collaborator did not work on UHD’s college algebra course per se, but his reform agenda for his linear algebra and differential equation courses, and his close collaboration with this group of three reforming algebra instructors provide important insights on planning and implementation of this case study of college algebra reform.

**Computer Enabled Learning Activities**
Computer-enabled activities are activities which require the use of computers, or activities that are significantly enhanced with computers. At UHD, the reformed college algebra course embraces visualization and real-world examples while taking advantage of computer speed in carrying out these activities. An overarching point that is made throughout this case is a need to have students use computers to carry out rote calculations, thus allowing them time to focus on conceptual learning:

Any instructor who has taught this course to beginning students knows that, if students experience difficulty, it's typically in carrying out the procedure. Where did I make my arithmetic mistake? So it's like looking for a needle in a haystack. It's not that the student doesn't understand the concept, it's that they've made a mistake in carrying it out, in the manipulation. So a high percentage of the time when you're teaching students these procedures, these algorithms to solve systems of equations, you spend a large amount of your time saying, "Look, you didn't multiply two times all of the left-hand side of the equation." We just said, for the sake of time, let's turn that over to the computer because the manipulations are only part of the problem, and that we really want to answer these conceptual questions at the end.

Visualization

Instructors in this course make use of visual aids in a similar way as a graphing calculator is used. They provide students a means to graph and manipulate functions with a friendly user interface. A computer is a lot more powerful than a graphic calculator, one reformer indicates, because it shows the graph in color on a 15" monitor or larger through a projection system. Graphs offer instructors an avenue to interact with students. Discussion can begin with a function's graph where students attempt to determine properties of the function, or vice-versa. One instructor explains the importance of graphing as a teaching strategy:

Those are certainly the high points; changing representation, beginning a problem with function, exploring properties by looking at tables more closely, or by looking at the graph, or starting with a graph and trying to develop the function formula. So we constantly go back and forth between the representation showing how you can illuminate certain properties depending on the form that you choose to work with, and we try and cut down on the tedious calculations.

Course discussion focuses on its central theme, functions, and it supports discussion on interpretation of functions, not on rote calculations. This fundamental strategy is based on connections between mathematical functions, and its graph and table representations:

Well I mean the whole course revolves around functions. Almost everything is done in that
context, so it's hard to narrow it down. We do lots of lab activities where we just explore some functions that have meaning to them, yeah practical. We do a lot of graphing and a lot of making tables of functions; so we take a formula and make a table out of that, or we graph that.

Student interaction seems to be an important learning strategy, and when visuals are utilized, student interaction increases. Students feel engaged when instructors use graphing tools to help them understand difficult concepts. One student explained:

I like the graphs. The instructor will ask what does this mean? And the class is like, Oh, I don't know; and he'll say, it means all the points in this plane. And then we're like, what plane? And then he'll show us on Maple, and it has like a 3-D graph and it shows the colored plane. And then suddenly we all understand what he's talking about. Or two intersecting planes, and it'll be like a line between the two planes. It has a very good visual interface.

Connecting to Real World Data
In this college algebra course, instructors attempt to stimulate students' interests and engage them in the learning process by coming up with examples from everyday situations. An instructor comments on this approach:

For example, in lab activities we give them a postage rate table, and ask them to calculate the postage for a letter weighing so many ounces. Another example is a single taxpayer with this much income. They are asked to calculate what will their taxes be? Or given a tuition table, what will the tuition cost be for a student enrolling in twelve credit hours? So all these examples come from their every day life experiences. It is true that some of our students have never worked with a tax table before, or gone to the post office and paid different than regular first-class postage. Nevertheless, these activities, because of their relevance or connection to real life, keeps them interested.

Connection to real-world problems is done in a way that lets students discover mathematics while interaction between students and instructor creates a sense of apprenticeship. Here's a student's viewpoint on this:

He would give us projects where he'd say, we have three companies and they produce these products. He would ask us a real-life question that would require that we use a matrix approach. But he wouldn't tell us how to set up the matrix or what variables to put where. You'd have to set it up on your own. I think that's a good way because it made us talk to each other. We got to know each other and we learned to rely on each other. You know, if someone had problems, we'd show each other how to do it.

There are additional advantages in using computers in curriculum. One such advantage is an instructor's ability to include, not just canonical problems that illustrate concepts, but more complicated problems with a real world context:

With the computer, you get an opportunity to do more complicated examples. Then there is the question: what's the meaning of the example, what's going on here. You might be doing an example from finance or from science, so you get a little chance to discuss the context of the problem. That helps them, I think, and gives me a lot more opportunity to interact with the students.
These sentiments are echoed by another student, namely that computers have an ability to expose students to more real-world problems. He explains:

*On the other hand, a lot of the faculty members like the technology because you can actually do some real world problems. You don't have to restrict it down to one or two digit numbers and only five data points when you are dealing with calculations. You can really do some high-powered nice problems.*

Finally, academic world stereotypes often suggest that teaching sociology or communication courses is more enjoyable than teaching mathematics because instructors can draw their students into conversations about content. With contextual examples and the use of visuals to illustrate concepts, mathematics instructors are able to create similarly enjoyable classroom environments. They are finding it easier to connect topics and make seamless transitions between one topic and another:

*Using graphs and providing context to problems also help me as an instructor...to make connections between topics...*

**Speed**

Earlier, when institutional goals and computer-based technology were considered, cost efficiencies was one important goal of the institution. Faculty, on the other hand, place student learning as their priority. Given the large number of under-prepared students at UHD, faculty are especially concerned with the utilization of classroom time. Specifically, instructors were asked if there was an attempt to maximize student learning using computers versus the time the students spent on campus. An instructor answered:

*You asked if technology helps you make more efficient use of class time? Yes, it does, because you might have spent a lot of time graphing functions by hand. That's a time consuming process. Your graphs are usually not very good, and the way that we teach students to graph functions by hand, it's not the way we do it usually in practice. We'll either use a tool, or we'll just roughly think about what the function looks like. Often we won't bother to draw a very accurate representation, or we don't need to draw a very accurate picture of the function in order to answer the sorts of questions that we want to answer, in practice. So I mean, yeah, technology is great for helping you spend a lot more time looking at graphs and thinking about what they mean and the information that they convey other than having to go through the tedious process of drawing. That's what is really important about doing graphs with the computer.*

While technology provides tools to produce quality visuals quickly and hence maximize student learning, this "extra" time was not used at UHD to pack more content into a given time period. Rather this extra time was used to consider topics more thoroughly.
Finally, using the computer’s speed to graph functions not only the students to focus on concepts as opposed to arithmetic, the students are also given the ability to perform many additional tasks and to consider more examples in a relatively short time period. This ability to work through more examples aids the learning process the students must go through and the instructor’s teaching process.

Enhancement of Student Collaboration
Collaborative learning is an essential part of this college algebra course’s reform. Students are asked to work together on problems in a group with a computer, and to interact with an instructor. However, success of collaborative methods in the Department of Computer and Mathematical Sciences is mixed from the points of view of both instructors and students. On one hand, instructors are still experimenting with ways to engage students in collaborative activities and trying to come up with a working model. An instructor explains:

*The collaborative learning I've experimented with takes many different forms. But I've yet to find one that really works for me because our student body is strictly a commuter one. It's hard to get set groups that can continue and build relationships beyond the classroom. How many students should make up a group, two versus three versus four? I don't know. And should it be set groups or rotating groups? Should you let them self select, or should you appoint them? So I've tried the different variations and I still haven't had one that works every time. So I think those are typical problems that most people have in trying to implement a collaborative learning method and technology.*

On the other hand, students do not appear to appreciate social benefits of learning in group work. They are still operating in a competitive individual mode, where everyone needs to outperform their classmates in order to progress. One student explains:

*As a student, I think there's advantage and disadvantage in doing group work. There's an advantage if you are a little slower than your peers. The advantage is for the one who comprehends the material slower than someone else; as such you will have ample time to benefit from your peer's knowledge. But it is a disadvantage for the one who learns quicker. He gets bored working with the group.*

Evidence of success
In getting colleagues to accept (not necessarily adopt) reformed ideas in a lower division required course like college algebra, it is important to have data that support the methods. At UHD, evidence takes the form of both anecdotes and tracking student performance data. This reformed college algebra course came at a time where a sizeable fraction of students were failing traditional algebra sections. Passing rates in the reformed course sections significantly increased in comparison to passing rates in traditional sections:
We went from 38% passing rate in 1996 in our traditional section to 46% passing rate in our "unified" technology section. We use the term "unified" to describe our approach. During the spring 1998 semester, the gap is even bigger. The passing rates are 35% and 51% for the traditional section and the unified technology section, respectively. That's quite an accomplishment.

The table below provides comparisons between reform and traditional sections over a two-year period. No only does this table contain passing rates in college algebra, it also shows passing rates for students in math courses which follow algebra:

<table>
<thead>
<tr>
<th>Semester</th>
<th>Type of Section</th>
<th># sections /students</th>
<th>Grade C or better</th>
<th>Grade C or better in next course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 1996</td>
<td>Traditional</td>
<td>6/202</td>
<td>38%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Reformed</td>
<td>6/185</td>
<td>46%</td>
<td>36%</td>
</tr>
<tr>
<td>Spring 1997</td>
<td>Traditional</td>
<td>3/91</td>
<td>38%</td>
<td>32%</td>
</tr>
<tr>
<td></td>
<td>Reformed</td>
<td>3/75</td>
<td>39%</td>
<td>26%</td>
</tr>
<tr>
<td>Fall 1997</td>
<td>Traditional</td>
<td>3/74</td>
<td>45%</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>Reformed</td>
<td>3/51</td>
<td>48%</td>
<td>29%</td>
</tr>
<tr>
<td>Spring 1998</td>
<td>Traditional</td>
<td>3/82</td>
<td>35%</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td>Reformed</td>
<td>3/69</td>
<td>51%</td>
<td>28%</td>
</tr>
</tbody>
</table>

Passing rates are not the only evidence of success according to the reformers. Instructors report that there is anecdotal evidence of the improvement in students' experiences, and that students seem to enjoy the course more:

Personally, I think that we may not be able to quantify success with passing rates alone. But in discussing with students, considering their overall experience, and reading some of the general comments, you do find a number of them who say it was a worthwhile course. Maybe they actually enjoyed it. We don't really have data that we could use to compare student perceptions to those from the traditional course.

If students enjoy being in this course, so do instructors. Before reform, classroom atmosphere was less then enticing for an instructor. Attendance was low, as was interest and participation. An instructor explains:

Yes, I can only give you anecdotal evidence, but the ambiance in the classroom is totally different as compared to before. The biggest thing that I've enjoyed about it is when you go into the classroom, you're not dreading going; you're not thinking how many are going to show up today; how many are going to be paying attention? Are they going to ask any questions? Am I going to get people to ask any questions? It's just a much different classroom atmosphere than before.

All faculty members in the department do not share enthusiasm about success of this reformed algebra course. Many question course content coverage and ability of students to use their algebra skills proficiently, a charge that is answered by one reformer as follows:

We did reduce the content in designing our unified course. But in tracking the students in later courses, there hasn't been any noticeable difference in performance between those who attended the traditional course and those who went through our unified section. A lot of
the skill that you teach them in traditional college algebra, again, you treat them so superficially that you wind up re-teaching them anyway in later courses. So the students in the traditional sections really didn't have much of an advantage because they didn't remember that one specialized skill they had been taught for one lecture. They didn't remember it anyway.

In many respects, objections of faculty who question methods are tempered by the fact that at UHD they do not have to adopt these reforms. They also imply that there is a certain amount of grade inflation in the reformed course, that students are graded on the basis of activities that have nothing to do with college algebra. One reformer responds to these allegations by bringing attention to data shown earlier in the table:

When you're teaching the college algebra course here, you can expect that the average number of times that a student in your class has taken the course is more than once, and that's on average. So I've had a lot of students who have been able to pass my reformed class, but weren't able to pass the traditional course. A lot of people will say, "well, there you go it's too easy. They shouldn't be passing". But in tracking these students, they seem to do okay, not any worse than other students in later courses. I think to at least have them be successful once in a college math course is important for them.

There is also skepticism on validity performance data (see table above) given that students enrolling in both the reformed and traditional sections are not selected at random. This is because the sections that rely heavily on computers are so noted in the sign-up schedule. The reformers point out that at UHD, however, that the dominant factor in class selection is availability and schedule of the section, not the methods used to teach content:

People always question the validity of those statistics because students self select the section they want to enroll in. The sections are identified in the schedule, so they know which sections are going to be using computers. How much that affects our outcomes? I don't know. But I strongly believe most students are selecting classes based on availability and their schedules. So I don't think that we're having a lot of people who are just gravitating toward the tech sections just because they want to be in that section.

Getting started

Even when a faculty member is faced with serious challenges in his/her learning environment, there is still a fairly high activation barrier in starting to develop a reform agenda. Potential examples of barriers at UHD are high teaching loads, their reward system, and student population demographics. In this section, we consider internal and external factors that propelled this group of three algebra instructors to begin their reform process.

Instructor Traits and Motivations
When queried about their motivations to start this reform effort, the faculty gave several reasons. There was of course the high failure rate for the course that they wanted to reduce. Also, as already mentioned, they wanted to change the atmosphere of the learning environment to make the classroom more enjoyable both for them and their students so they didn't have to think about "...how many [students] are going to show up today; how many are going to be paying attention? Are they going to ask any questions?" Another motivation came to light when one reformer was asked if they used computers at UHD to optimize classroom learning and make efficient use of students' classroom time since most students are commuter students working part- or full-time jobs.

*I wouldn't say we use computers to optimize the learning time, but it's to accommodate more learning styles. Some students are better, of course, visually, auditory, hands, skills, and so the computer somehow seems to tell students or inform them, illuminate them in ways sometimes that we can't do using the board. It seems to be another dimension for them as a learning tool; and so by presenting with it, somehow you sometimes reach a student that nothing else could have reached.*

Computers seem to provide instructors this new dimension, or teaching strategy, that might reach a student with a different learning style. One issue that was not a motivation for these reformers was to pack more content into the course, and into the students' brains, when they are physically present by using a more "efficient" teaching mode. Instructors were more interested in improving quality of learning experiences.

**External Factors and Support**

There were also external factors, some of them serendipitous, providing an initial environment that allowed this algebra project to incubate. One external factor, the Interactive Math Text Project (IMTP) funded by IBM and the National Science Foundation occurred early in 1990. "The Interactive Mathematics Text Project had as its goal improvement of mathematics learning through use of computer based interactive texts. To achieve this goal, IMTP held summer workshops on use and authoring of texts and supported selected individuals as text developers." UHD was one of six national sites selected for these workshops:

*Well, actually the history goes back to the IMTP. That's what got us started in this here. This was a program that was funded by the IBM and NSF for MAA, and directed by Jerry Porter from the University of Pennsylvania. We were one of six sites selected across the country. I was the project director for our campus site, and that's what got us involved mostly in the technology here, using some form of technology in the classroom.*

IMTP workshops gave UHD's math faculty access to then state-of-the-art computer equipment and software. It also provided faculty exposure to national reformers and reform ideas in mathematics:

*In 1992, there were some computers put here because of the IMTP, whose results, I think,
were not all that great. But people were coming here. Realize that the IMTP infrastructure was put here, not for the faculty, but to hold workshops. Of course, we got to use it when it wasn't otherwise being used. That was kind of an initial catalyst that provided us equipment access.

In order to validate a reform plan in colleague's eyes, methods being considered were aligned with a reform movement with a national reputation. For UHD's group of soon to be reformers, Harvard's calculus reform movement provided this anchor. All of a sudden, faculty had access to computer equipment, software and reform-oriented texts:

We began this work because of the mother of all reform programs, Harvard Calculus. What got us started were the problems [high failure rates] we had before. We knew about reform in part because of the IMTP, which was itself influenced by Harvard. There were these two things that were sort of converging. Technology was more accessible because of the IMTP. Then these reform texts were being published at about the same time.

While IMPTP provided computer access to faculty, there was a lot more investing needed in order to begin implementation of reform in this college algebra course. Real reform would provide wide access to computers for, not only faculty, but also for students, as well as faculty time to develop new curriculum. UHD'S group of three found an invaluable resource in NSF ILI's grant program. It provided them initial funds that externally validated their plan in their colleagues' and administrators' eyes.

I don't know what NSF's view on equipment is anymore but ILI grants used to be a really terrific resource. I don't know if the NSF thinks now that all universities can afford their own computers, but that's a place to start looking. We also had the Interactive Mathematics Text Project (IMTP) workshop in the early nineties, which gave us the initial hardware and some software for college algebra. Then there was a curriculum development grant, which we used to buy release time for developing curriculum.

Implementation: Institutional and cultural issues

Organizational issues are akin to the institutional context provided earlier. However, focus here is on specific institutional factors that have affected reform in college algebra.

Rewards

UHD has a number of incentives for faculty who excel in teaching. One such incentive is their university-wide teaching award. While an administrator is quick to point out that these awards have no substantial financial benefits, they are considered prestigious among faculty colleagues and administrators. It is interesting to also note that teaching reform with technology is considered important enough at UHD that some individuals have received an award several times in row. In fact, the principal worker in this college algebra reform was awarded a teaching award six times in the
The teaching awards are institutional here. In the last seven years, Professor Waller has won the teaching award six times. This college, the College of Science and Technology, and I remind everyone of that, has excelled in teaching.

Aside from prestige, the University also offers financial support through their Teaching with Technology Learning Center. TTLC offers small grants often used as assigned time to help faculty initiate courseware development with technology. A faculty collaborator explains:

The University was very supportive in that sense. There was equipment support, and small grants from TTLC, Teaching with Technology Learning Center. The Center has grants to give you to do activities like this. You can apply for faculty development there; you can get money to develop these things; so there is support from the administration to do things like that.

Status
Use of technology in one's curriculum reform does not seem to bring much status to UHD faculty. There are two avenues for being recognized when doing such work: First is the teaching award mentioned above. It is important to note that the one time that the college algebra reformer was not awarded this teaching award during the last seven years, another collaborator himself active in technology-enabled reform received it. Second, UHD enjoys exposure and marketing benefits from technology work done by its faculty. As a result, faculty involved in these activities enjoy a small status advantage.

Cultural Shift
Implementation of reform at UHD has had its challenges both in terms of getting it accepted by faculty colleagues and students. The faculty's central objection was the issue of content reduction in the college algebra course, as explained by one of the reformers:

I think the biggest challenge is trying to get your peers to accept the idea, the change. That still hasn't happened. The main issue has to do with content. They feel like content is being taken out. In addition, they are not familiar with the technology. They don't want to change; they don't want to learn anything new. They don't want to change the way they teach. Fortunately no one has told us we can't do that.

Technology use also provided some peer pressure for colleagues to use modern techniques to at least present, if not reform, course content. At this time, faculty colleagues feel very at ease that they do not have to engage in these activities, but some are wondering, if in the future, they will be asked to. An administrator gives his assessment of faculty's and students' views on the math department's use of technology:
In the math group, you'll find a lot of faculty who are very resistant to using very much technology in the classroom. In courses like college algebra and calculus, many of the instructors still want to use the old methods. They are finding that a lot of students are reluctant to accept the technology as well. When we can, we'll put in two sections at the same time, one being a regular and another using some technology. When we do that, we find a lot of switching around as we move along. I've had students come in here and say, "I don't want to buy a calculator, or the course I had, I'm repeating it, I don't want to learn something new. I want to do it the old way."

Very quickly one is reminded of the UHD culture where any reform, even if it is successful, cannot be imposed onto other colleagues. The departmental environment appears to be very compartmentalized. Each group managing one or more courses is fairly free to implement new approaches, as long as others are not asked to use them. Use of these methods do not seem to have created department conflicts, or affected tenure and promotion decision processes:

I don't think that there has been any kind of problems or conflicts. The faculty seems to be happy with the fact that it's ok to use various methods, as long they aren't forced on the rest of us. That is sort of the attitude. So I don't think there's any problem at all. People are, I think, working together very well in the department in terms of the program committees. Whether they use technology or didn't use technology has not been an issue in terms of getting tenure.

Students also have not been easily convinced of the efficacy of the new approach. Given that they will spend a limited amount of time on campus activities, any activities they perceive as superfluous are not welcomed. A collaborator comments:

Another thing is to convince the students that these computer-based activities are good for them. That still continues to be a problem because they don't see the need for these methods. They want to do it fast and go. My job is to convince them how very important this type of activity is for them.

The students' resistance is more than just a time investment issue. They are still not entirely comfortable with using computers, and have completely internalized the traditional methods for teaching mathematics. One reformer explains:

The computer is still something new to our students. Talk about student resistance, I've had this comment more than once and this is really funny. They'll be complaining about the way the course is taught and they'll say, "You know I've had this course before" meaning that they've taken it and either dropped it or failed it; "I've had this course before and this is not the way it's supposed to be done." So even though they may be successful in the technology-based course, they are still telling me that I've got to get with the program. "You're not supposed to be teaching it this way." They'll say this is a math course. This isn't a writing course, why are you asking me to write a sentence?

**Organizational Savvy**
Getting reform implemented in UHD's college algebra course at UHD has required
little organizational know-how. Classroom and laboratory modifications needed for reform to take hold were and are being done by the college for reasons not directly connected to college algebra. One important change worth noting was the reformers’ ability to get UHD to agree to commit one technical support person to their department, as opposed to relying on lesser-responsive college-wide technical staff:

In terms of having our own technical support in the department, I guess we’ve been able to convince the administration that it’s a necessity. The reason is that we got external grants to build the lab, and in the grants, they promised that we would have technical support. So they didn’t have much of a choice if they signed off on it to go along with it.

Implementation: Technical resources

Technical resources needed by the reforms from UHD fall under two categories: Equipment/hardware and technical staff support.

Hardware

Nearly all computer and mathematical science department instructors at UHD who use technology in their classrooms pointed out problems with computer hardware reliability. Sometimes, the problem was operating system robustness; other times it had to do with contaminated software before class and laboratory activities. A collaborator reflects on his frustration with hardware:

“It was hard for me at the beginning; really, I mean I was completely frustrated. The machine will break down on me; my God I’m going to have a fit. This is the way it was. It was lousy; you expect everything is going to be perfect, and it’s not perfect, by no means. There will be bugs here and there; the machine is going to break down.

Technical Staff

Adding a dedicated technical support person to the department has significantly reduced technical problems experienced at the beginning of the reform efforts. A faculty collaborator explains:

In the past, getting the lab ready in the sense that students can use and there won’t be any problem during class time was an issue. Before we had problems like crashing for example, or the computer wouldn’t start. Now we have much better technical support than we have had in the past. Our support person is now entirely devoted to the department. That is a big difference.

This improvement in technical support was more a result of the fact that a staff person was located right in the general faculty office area. It made it very easy for instructors needing technical support to simply drop by the next door office, rather than seek help from the distant Teaching
with Technology Learning Center with its university-wide technical support responsibility. The technical staff person comments on this:

*I think the faculty like that I am near them, and feel comfortable working with me. I think they prefer to come to me. They do so because the TTLC, for example, not only assist our department, but everybody in the university; so it will take a longer time for them to get help. If they come to me, I usually have probably less things to do, and get to them a lot quicker than the TTLC would.*

**Implementation: Non-Technical resources**

**Time and Workload**
There are many issues that can stymie reform. The previous section focused on two obvious, tangible issues: hardware and technical support personnel. Somewhat more elusive is finding the time to implement reform programs. Specifically, is the reform effort placed on top of an already heavy workload? In addressing the workload issue at UHD, an administrator is quick to point out TTLC’s small assigned time grant program:

*At this institution, we have the learning center in the technology area. Based on a short proposal, it offers small grants to professors competitively. It’s a positive approach. I’ve never found that the punishment approach works.*

However, a major impediment to the kind of reform implemented in college algebra at UHD is time availability, or lack thereof, for instructors to design new curriculum methods. With a four-course teaching load per semester, committee assignments, and extensive student contact hours, finding blocks of time to work individually, and collaborate with others in curriculum matters is nothing short of a miracle. Because of additional learning activities, such as group work, technology use in teaching courses also comes with an increased workload. At UHD, this added workload is handled without student assistant help. An instructor comments:

*Using technology, my own workload of course has increased tremendously. I’ve never done a course where I had to grade exercises, labs and projects; it does increase my teaching load, not the number of teaching hours, but the kind of work I do. I want to collect homework, and I want to collect the labs, the projects, and grade them myself. We don’t have graduate assistants to help us in this process.*

There is some concern about the possibility that these reformers may burn out, particularly if the work environment continues to assign the same workload to faculty regardless of the kind of activities offered and the methods used.

**Implementation: Personal attitudes and peer support**
Attitudes and Teaching Philosophy

At the root of this ten-year commitment to implement reform in the college algebra course at UHD are the reformers’ attitudes and teaching philosophy. What values made this reform happen? Playing the skeptic, we asked if all this was to make the course more appealing to students, a somewhat superficial objective for using technology. One of the reformers who answered provided some interesting insights into his classroom teaching philosophy:

*I don’t think we were thinking of using technology to make the course sexier; that was in the back our mind. They [students] come in with weak skills and so we were using the technology as kind of a skill replacement; we wanted to do a little bit more relevant problems. We wanted to present the material in a different way; we didn’t want them to be repeating their high school algebra class. Technology really gives you an opportunity to sort of remake the course, we call it reinventing the course, so it gives you something to structure your syllabus around.*

We also inquired about technology use to interact and communicate with students, in light of the fact that many students are working long hours outside UHD. Another reformer answered:

*We don’t use technology as a communications tool, mainly for content. One great thing about the technology, it really gives you a good context for interaction. So if they’re doing something in class, for example making a graph, it gives you a good opportunity to talk with them about that graph, or have them ask you questions about it. It really helps bring the instructor and the student closer together.*

The road to reform has had its bumps, from faculty outside UHD using the curriculum material developed for the course and from faculty inside UHD in the Department of Computer and Mathematical Sciences. The reformers have had to make a case for reducing some of the content and skills taught in the traditional course. They questioned the old paradigm of teaching students every detailed step in the mathematical solutions to canonical examples. In line with the national reform movement, they included in the curriculum problems with real-world relevance. Here is how they made their case:

*In many cases, some people say, "you didn't teach them step by step way of solving a three by three system of equations, which is a standard part of the curriculum". People who have used our material off campus have complained about that. But that's a decision that you*
make, and here is why you might come to this sort of conclusion. Look, when you're teaching them to solve a three by three system by hand, what really are you trying to teach? There is something useful there, there's the whole idea of substitutions. What else is there about solving a system of equations that's truly useful? What happens often in algebra courses is that it's never pointed out to students that this is a problem solving method that's really useful in other areas as well. It merely becomes a blue box in a book; follow these steps to solve a system of equations. When it becomes that rote, all the value of the method is missing, but all the pitfalls are still there, the arithmetic mistakes, all the things that frustrate students. So we simply said, what students learn by us teaching them elimination is not worth it at this point. We'll just let them solve the system with the computer, which is the way they're going to do it in practice anyway. They're probably not going to do it a lot by hand with a realistic system of equations, maybe for small systems like a 2 x 2. So those are the kinds of decisions that we were facing throughout the curriculum. It was what's really important about this problem, and then how important are the skills, sort of the manipulative skills that you have to have to carry out to the next level.

A faculty collaborator reinforces that case for reform by using his experience in linear algebra at UHD:

Now my experience so far teaching this class has been relatively successful. In a course like linear algebra, from my point of view, if I were to do the traditional way, like theorem proof type thing, I don't think that it would be of value to our student, and they would not appreciate it. Now in the interactive setting that they do, they're creating something of their own. They have to create their own examples; the examples are there, but they can change the examples and try to conjecture out of these examples what's going on. They can derive some of the concepts, but proofs are very minimal in this course. So that's basically what I do in this linear algebra course.

When this same collaborator was asked why he continued with the reform path even though he faced a series of daunting challenges (increased workload, technical difficulties, etc.), he replied:

Yes I could have quit, but I felt a value in it to me because I saw the utility of these packages, in particular in my case, Maple. I saw how important it is/was for me to make a presentation, and make a dynamic environment in the classroom using these software packages.

In reflecting back over the last few years of reform, one instructor considers the many benefits of including technology-based activities in the college algebra curriculum:

People who are thinking about using technology maybe just wondering what it offers. It really gives you a kind of opening up in the classroom, a lot of avenues for discussion. Sometime when you're lecturing and you're so focused on finishing up five examples, or whatever you had planned for that day, you're really just reciting this material. You ask for questions, but it's kind of perfunctory, and of course the students don't ask anything. They're willing just to sit there also and let you regurgitate this material. On the other hand, when you are trying to do examples with technology, when you're making graphs in a math class or showing graphs, it always, to me, raises points of discussion. There's always something that you see in the graph that suggests something to you that maybe you hadn't thought about. When you're doing more complicated examples than before, it brings up the whole question of what's the meaning of the example? What's going on here?

Peer Support
At educational institutions, even those that are teaching-focused, there is a limited financial gain for the faculty willing to engage in curriculum reform. Often, the institutions provide some financial and/or space support only after external foundations, such as NSF, have approved that project. Peer support is a thread that usually keeps reformers engaged and motivated. A variety of reasons (such as the Interactive Math Text Project, IMTP, workshops in the early 90's) resulted in UHD college algebra reformers receiving external support early on for their reforms. Peer support was important, not to get the project started, but to continue its implementation over a 10-year period. One should also note that this reform project relied upon a close working relationship among three faculty members for nearly 10 years. UHD's environment encouraged, or allowed this relationship to flourish. One reformer spoke about the commitment required to continually build support from departmental colleagues:

> You have to constantly sell yourself. Give it a chance, there will be times you'll be lost, there will be times you will be confused, but if you're patient and keep trying, then things will get better; but it's not always smooth sailing, it's constantly trying to convince them that it will work in the long run.

The environment at UHD is unusual in that faculty are free to experiment with small curriculum segments, as long as they do not attempt to impose these changes on their colleagues. While departmental support per se was not evident, changes implemented in college algebra were also not opposed by the department.

> Well the department pretty much has no string that we have to do things in a certain way; so they've been very supportive in the sense that let us pretty much try anything that we want. And so we've streamlined the curriculum, we've brought in technology, we've tried collaborative learning and never have we been told, stop doing something.

### Implementation: New instructor roles

"...In other courses, you naturally start thinking about why am I teaching this course this way? Am I just teaching it because this is the way I was taught..."

**Role**

UHD’s implementation of college algebra reform has had an enormous effect on faculty in their role as teachers. Simply put, faculty involved in this reform went from a passive teacher model to an active facilitator or coach model helping students in their learning process. In that new role, they have faced some students' frustration since students expect a learning environment where the teacher present content and students sit passively and listen. One reformer describes this new role:
Well I think we’re all sharing the same experiences. The old fashioned way of the lecture method is very efficient. You have a syllabus and, if the students don't ask any questions, you can say, "well even if they don’t understand it, I've covered every topic on this syllabus." So you try to stop being the sage on the stage and become a facilitator. You try to become someone who tried to initiate discussion. Of course, there goes your time. You don't cover everything that's listed on the syllabus. Sometimes instead of trying to give answers directly when they ask a question, you try and give hints to get them to see what the answer is, what points they're missing. As a result, I sense a little bit of frustration. "Why don't you just tell me the answer?" I try and get them to be more independent learners, to learn to teach themselves, to be lifelong learners. So how do you accomplish that? I don't know, but it's not by just giving answers. I know that much. So it has influenced me in every one of my courses. I try not to just become an answer machine but someone who somehow engages the students to break down problems when it's not working so that they can become better learners.

This reform process has other benefits as well, namely richer interactions with students and an opportunity for faculty to reflect upon their curriculum and teaching methods:

I feel like it has made me a lot closer to the students. I think I talk with them a lot more. I understand their point of view a lot better; so I think it made me connect to the students a lot better; just thinking about changing the curriculum makes you a better teacher all the way around, in all of your courses. In other courses, you naturally start thinking about why am I teaching this course this way? Am I just teaching it because this is the way I was taught this course, or just because this is the way the textbook presents the material? What's a better way to teach the class? And for someone who is thinking about technology, that's just a side effect, that's a real benefit. If they really have to think about how they're going to incorporate technology into their classes, just naturally they're going to start thinking about the curriculum. They're going to benefit from that, being reflective about the curriculum.

Faculty changes does not appear to be exclusively limited to this college algebra course. These instructors are bringing this newfound knowledge and practice to other courses as well. One of them comments:

To me, it changed the way I teach all my courses. I haven’t been teaching math courses now for five years. I’ve been teaching exclusively computer science courses. But in those courses, I used that experience in the way I present the materials. I always give an example first similarly to engineering. We have example and tie it into the concepts. That's the way I now teach all my courses.

In teaching courses where no reform methods have yet been applied, these reformers are finding it difficult to adjust to old ways, and they are identifying numerous opportunities for including reformed-minded activities:

I'm teaching a remedial math course and I haven’t done that for a long time. It's intermediate algebra, so it's really high school algebra in one semester. I haven't had time to work on developing anything; so there's no software, it's a blackboard lecture style class with no cooperative learning in it; it's just very difficult for me. I'm all the time thinking, I see all these opportunities where we could use technology, or all these places where I wish they had a group activity to work on, where it's just fruitless for me to stand there and talk to them. So what I'm saying is once you've engaged in this kind of reform, you realize that it's powerful. It has something to offer.

It seems that having gone through a reform experience, one realizes that these
methods offer both power and opportunities.

Implementation: Student issues

The one audience not yet addressed is the students, and how the change to a computer-enabled curriculum affected them. How easy was it for the students to use the new technology? Did it change their workload significantly up or down? Did they have easy access to the computers needed to complete this course? To what degree has computer use in this course improved or deteriorated the learning environment in their eyes?

Ease of Using Technology

Implementation of computer-based activities in this college algebra course initially faced resistance from students, not because of typical computer access issues, but because of the software interface used in designing the activities. There were syntax and programming skills required to be proficient to use programs like Mathematica or Maple which were too demanding for lower-level students. An instructor explains:

"Obviously we couldn't teach them in college algebra anything about Mathematica. It's difficult to start with, and they're going to resent and resist that; they'll say this is not a class about programming this is algebra. So we created a visual basic interface; this was one of the first technology things we worked one because we wanted to use Mathematica or Maple (we just started with Mathematica). We wanted to see if we could use it in the lower level courses and have an interface that will allow them to carry out certain operations in Mathematica, without any of the programming. It's a fill-in the box kind of interface.

The solution to this problem was to develop a visual basic interface that would provide access to all computational and graphing tools of Mathematica, but interface with students with the ease of a scientific calculator. With this interface, students could focus on learning college algebra concepts rather than focusing on programming issues."
Figure 3. The MILTON computer interface using Mathwright®.

Change in Course Workload
If students at UHD thought that using computers in college algebra curriculum would reduce their workload, they were mistaken since the apparent course workload has increased. The student are now required to engage in more activities that they had to do before. Moreover, simply doing these activities does not necessarily lead to a course grade of "A." The student have also discovered that active learning is hard work. A faculty collaborator comments on his experience reforming linear algebra:

*Now you see, the students are finding that, especially in linear algebra, the use of technology is taxing them a lot. They have to do all this work and eventually they may end up getting C's and B's. At the very beginning, using the technology was like a sort of grade inflation. Then after I learned my lesson in a few semesters, things changed. They think if they do all these activities then automatically they are securing a B or an A in the course; many of them are disappointed after they end up getting C's or B's. They feel that it's too much work on them, doing all these things, given that they are transit students; it's not like that's the only responsibility they have.*

This is an important observation since it is often incorrectly believed that computer use in a classroom reduces the time required from the student. Though the increased workload may initially be accepted by the student, if every course the student enrolled in required a significant increase in workload, problems would undoubted surface.

Ease of Access to Technology
Traditional issues of computer access have not surfaced in UHD's college algebra course. This is surprising given the fact that UHD provides services to a working
student population. There have been issues of access but these focus more on the students' inability from a financial perspective to obtain the latest software versions. In choosing a software platform, the reformers' first and foremost priority was to choose one with effective internet access. That way, only the instructors had to have the most current software, and the students were no longer financially responsible:

We're talking about the software continuously improving. You can't expect a student to keep investing, investing and investing as upgrades and improvements occur; that's the one fabulous thing about the internet. It's becoming so available everywhere at essentially no charge to the student because schools are providing computer labs and sometimes even giving students computers. That way you can keep updating the software and the interface without any expense to the students who will take advantage of the most current technology by simply being connected to the internet. This is especially important for our student body; just textbooks are a major expense for them, and to in any way burden them with something beyond that, they don't like that. They'll choose other options if they're available rather than spending extra money.

Increasingly, students who own their own computers are purchasing student software versions. They are finding it convenient and helpful in being able to access software at home. One explains:

Actually, I think I retained more the material than I would have if I hadn't done it with the computers. This is so because I have the Maple software at home and I still use it for other things. It's still pretty fresh in mind.

Improvements or Detriments From Use of Technology

"You don't get all caught up in doing the calculations part of the work. You can actually focus on the concepts..." The effects on student learning in college algebra as it relates to the use of technology depends upon who is asked. Students generally feel that technology provides them a means to work on more complex problems, and focus on interpretation of concepts and learning through parameter variations, instead of working out tedious calculations. One explains:

You don't get all caught up in doing the calculations part of the work. You can actually focus on the concepts. For example, if you're going to see how a transform is going to affect a larger matrix, you don't have to sit there and do every single entry, which would take forever by hand. But you can do, like a six by six matrix on the computer. It'll go through it real quick and it'll show you the results. You can change the values and see the effects, you know? If you did it by hand, you'd have to wait, like, ten minutes just to see the result. You get really tired of just doing the work itself.

Some faculty stated that students are expressing frustration because of the increase in workload. A collaborator is not convinced that all students are benefiting from these computer-enabled activities:

The more you involve them in the technology, and demand from them to use the technology and so on, the more frustrated they are. They don't like it that much, not all of them. Last semester, in my linear algebra class, I would say out of twenty students, probably seven to eight were doing really well. The others were carried over by those ones, somehow.
Roles
There have been many positive gains in including computer-based activities in the college algebra course at UHD, one of them being the change in the students' role. Students who have traditionally come to campus only to attend classes, are now being engaged in community and group activities. They are talking about mathematics, as explained by a faculty collaborator:

*In general, the students come in, take classes and go; but this type of activity is getting them to know each other, be with each other, and talk about mathematics. In no other class they get to talk about mathematics. But now they are saying words in mathematics and discussing math problems.*

However, this change of role has not always been a smooth one. There is a strong continuous pull on the part of students for the reformers to revert back to the traditional teacher-students paradigm. They feel comfortable in the traditional setting even if they have not been successful in it. One of the reformers comments:

*They resist the change to a technology-based curriculum. I mean even if they're failing in the traditional classroom, they're failing comfortably. They're used to teachers coming in, lecturing, writing on the board, assigning problems and doing practice problems. Maybe the homework are worked on, maybe not; they come in to test day, they are going to see problems just like the ones you've been practicing, and so they're very comfortable with that. That's essentially their entire experience that they've ever known.*
Figure 1. Number of graduates versus ethnicity at UHD from 1990 through 1994.

Student Ethnicity 1990-1994

Figure 2. Demographics of UHD by ethnicity from 1990-1994.
Figure 3. The MILTON computer interface using Mathwright®.