WORKING DRAFT

Strategies for increasing success of students underprepared for math topics in Advanced Technology Education (ATE): Getting students into and through ATE programs of study in Community Colleges

by

W. Charles Wiseley, Ed.D.

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This working paper draft is made available to provide insights to recent research into ATE programs reporting high success rates for students under-prepared in mathematics. Comments can be sent directly to chuck@wiseley.org

STRATEGIES FOR INCREASING SUCCESS OF STUDENTS UNDERPREPARED FOR MATH TOPICS IN ADVANCED TECHNOLOGY EDUCATION: GETTING STUDENTS INTO AND THROUGH ATE PROGRAMS OF STUDY

A number of authors discuss the low numbers of U.S. college completions as a “crisis” in education and more particularly, a “crisis” in the progress of students through developmental education in community colleges (Grubb, 2012; Grubb et al., 2011). That crisis might better be framed as a problem of magnitude, the number and percentage, of students tested and placed into remediation who never progress into college level studies. The “crisis” language is used to call attention to the growing problem (Grubb, 2011) of what Scrivener and Weiss (2013) call the “nation’s seemingly intractable completion problem in community colleges.” The crisis is particularly evident in mathematics instruction and the content areas that depend on math skills such as Advanced Technology Education (ATE)[1] such as engineering, computer science and biotechnology.

Pamela Eddy, in her chapter “The impact of state policy on community college STEM programs” (Palmer and Wood, 2013) describes this crisis as “declining college graduation rates, poor performance in mathematics and science, and an increasingly competitive and technology-driven global economy” (p. 17). Research indicates that approximately one-half of all incoming students are underprepared for college, needing remedial work in at least one subject, and some community colleges claim as high as 90% of incoming students need one or more developmental courses (Perrin, 2011). While the majority of colleges offer developmental coursework, statistics confirm that less than 25% of students who enroll in remedial or developmental classes go on to finish their degrees. More disappointingly, recent research on academic progress of developmental math students in California community colleges suggest that less than 12% of students in developmental math courses ever complete a college level math course (Bahr, 2008). Given that research, there are intensive efforts to

[1] ATE programs focus on the education of technicians for the high-technology fields that drive our nation's economy. The National Science Foundation (NSF) created the ATE Program to improve and expand STEM (science, technology, engineering, and mathematics) fields. The program is congressionally mandated and focuses on both the undergraduate and the secondary school levels. (AACC, 2014)

identify and expand the more innovative and effective developmental education sequencing of mathematics.

This paper is about the critical importance of helping community college students get into and through ATE programs of study and how colleges can rethink their practices to increase rates of program entry and completion. The research is an investigation into the methods of moving developmental education level students needing developmental mathematics support into, through, and out of ATE programs used by NSF funded ATE programs and centers. While there was some direct observation of classes in our research, the bulk of the research for this paper was completed by surveying and interviewing Principal Investigators (PIs) and faculty in National Science Foundation (NSF) funded ATE centers.

While we continue to find new and more effective ways to move students through developmental education, there is very little scaling up of those innovative and effective ways to help students acquire the skills they need for further education (Grubb, 2012). Even with many of those effective practices being identified with solid random assignment research (MDRC, 2010) and very large sample quasi experimental research (Wiseley, 2009), very little scaling up within institutions has occurred. In the past two decades efficient and effective practices have been identified that engage students sufficiently to increase progress and success in developmental courses and although a number of dissemination efforts have been initiated, many effective practices still can be seen as small pockets of instruction in institutions that affect only a few students or a few dozen at most.

Corbin Campbell, principal investigator for the College Educational Quality project, and a team of 10 graduate students investigated academic rigor and teaching quality in two selective research institutions, one public and one private. Her team observed 153 courses and analyzed 149 syllabi in the spring of 2013. They found that:

> … most of the faculty members failed to use effective teaching practices. Just over half of the observed courses included in-class activities. About 40 percent had discussions. Classes with those attributes yielded significantly higher scores for academic rigor and teaching quality than those without them. (Barrett, 2014)

Their research found that courses with class activities, class discussions, or where students asked questions scored statistically significantly higher on all scales for academic rigor and teaching quality than those without those activities (Campbell, 2013). In ATE programs, where innovation is a standard, our research suggests that class activities may be the most important attribute to increase completions.

Our research tries to untangle those aspects of instructional practices and strategies that are being used in ATE programs and which practices are reported as most effective by NSF funded ATE practitioners.

Pipeline to Pathways

The **Pipeline to Pathways** research began with a survey of 540 ATE funded project Principle Investigators over 10 years (2002-2011) with 156 responses (29%). Of those responses, the research to determine strategies and methods of moving developmental education level students needing developmental education support into, through, and out of ATE programs looked at the 56 respondents who reported some curricular supports for developmental education students. Those 56 respondents were contacted by email and then telephone to set up a follow-up interview. Eight interviews were conducted with those who had supports for ATE students needing developmental math support who agreed to be interviewed.

The Pipeline to Pathways team also did a number of site visits over the term of the study. The team observed classes in a number of institutions leading to ATE programs during the study. While the visits led to a number of papers and follow-ups, one visit in particular is presented here to show how the bulk of those not directly supporting developmental students into and through ATE programs operate. The institution presented was using technology as an innovation to “help” developmental math students. At that institution, what I will call Tropical College, observations included a prealgebra course in a traditional math department, a Quality Assurance course (introductory biotech course), and a NSF funded lab workshop in a biotech program. Both the math and quality assurance courses were instructor lead and had very little student-instructor interaction. Student activities in the math course used computerized math homework problems that were required prior to each class. The instructor solved various types of math problems with increasing difficulty over the class period using problems from the math instruction software projected onto the whiteboard. Personalized instruction occurred in the computer lab through student-instructional aid interaction and computerized homework practice and quizzes.

The math department faculty at Tropical College interviewed reported that about half of their students pass courses with this type of instruction at their institution. The biotech instructor, however, reported amazingly high success in his laboratory workshops with high completion rates for those students, although, to recruit students he did select those already exhibiting characteristics of a good student. He recruited a few of those students each year and helped those students develop a “scientist” identity by having students work through applications of biotechnology processes on actual experiments that were important in the local environment.

Students were started on the most rudimentary collection and analysis and progressed over the term to more complicated processes and equipment. He and his lab assistant worked with students individually on projects, as they learned to apply the math and processes learned in their regular lecture courses. Those same students were, however, disengaged during the Quality Assurance and mathematics instruction/instructor problem solving that we observed as were many or most of the other students, respectively, who were reading email and texting during the class.

A short aside here might help the reader understand the particular institution and the description of the prealgebra math class. Tropical College has different math requirements for STEM programs and non-STEM programs. The typical success rates for the classes were reported as similar to the generally low success rates cited by Bahr (2008) and Perrin (2011) for prealgebra. A math computer lab was created approximately seven years prior to our spring 2013 visit. Students are required to do their homework on computers in the math lab. Computers in the math lab use the student login to track student progress in their homework and extra practice problems. The software, EducoSoft, “integrates content with Learning Management System (LMS) features for teaching in a traditional classroom environment (web-enhanced course) or distance learning environment (web-based or online course)” (from the software website at http://www.educosoft.com/), and according to the faculty interviewed, is used in most of the classrooms for both classroom demonstration and class homework requirements at Tropical. The math lab technician suggested that although the software is available on the web, most of the students did not have the computers at home or high speed internet access required to run the software over the web. And, after seven years, the first pre/post-implementation research was being conducted by one of the department faculty.

This is an example of one of the many new instructional practices that have not been or are just beginning to be evaluated but are scaled up throughout college departments and institutions (Scrivener & Weiss, 2013; Scrivener, Weiss, & Teres, 2009). While some of those practices seem extremely effective for increasing learning (and are touted as such), such as the flipped classroom, modularized instruction, self-paced modularized instruction online, etc., evidence to evaluate the systems for increased learning, retention, and persistence are just beginning to come in (Herreid & Schiller, 2013; CPC, 2014).

The Tropical College math class observed was also an example of the disengaging developmental education instructional practices that Grubb and others revealed (Grubb & Gabriner, 2012; Grubb, Boner, Frankel, Parker, Patterson, Gabriner, Hope, Schiorring, Smith, Taylor, Walton, & Wilson, 2011; Grubb & Associates, 1999). The math instruction was strictly behaviorist with the instructor doing all the problem solutions on the board, with his back to the students, and no direct questioning or comments to students. The disengagement was evident as 15 of the 26 students came late (as late as 40 minutes) for the 90 minute class. Once there, many of them answered email and texts on their phones. Table 1 shows counts of verbal interactions in the class session. There were 41 questions posed by either the instructor or students and most of the 33 instructor questions were a prompt of “class?” as he waited a moment before writing the solution or next step of the solution. Only 12 of the 26 students responded to a question and only six students responded to the occasional prompt of “class?” more than once.

The questions posed by students initiated student responses in all cases but two. In those two cases, the instructor restated the solution using the same words and underlined the solution components written on the whiteboard: similar to what was observed by Grubb et. al. (1999) when instructors would use the exact same words they had just used to answer student questions rather than address the question/solution in a new way.

Looking at the group response method of participation and evaluations of understanding used in the class, there were 12 students who responded to at least one question posed by either the instructor or another student but less than 24% (6 students) responded more than once during the class session. More importantly, less than a quarter of the students participated in any of the class inquiry-response interactions more than once. Fifty percent had no audible interaction at all during the hour and a half session. Nearly all the verbal interactions were by female students. Only two males interacted verbally during the class session and then only once each.

Table 1
Student classroom verbal interaction participation in Math 120E class.

	Interactions	Students responding at least once		Students responding more than once	
Category	Count	Students	%	Students	%
Questions posed **by Instructor**	33				
Questions posed **by students**	8	6	**18.2**	**2**	**6.1**
Students respond to questions[a]	41	12	**36.4**	**6**	**18.2**
Volunteered comments[b]	15	6	**18.2**	**2**	**6.1**
Overall student participation	60	13	**39.4**	**8**	**24.2**

Note: N = 26 students.
[a] Responses include answers to questions posed by either the instructor or another student but not those in response to another student statement or response.
[b] Comments include statements and comments not prompted by a question but added as additional information, explanation, or disagreement with a previous statement or response.

Given the requirement for students to do homework and practice that is tracked on the LMS in the lab or on the internet, the instructor may have been aware of student work either before or after the actual class sessions. Even so, the lack of student participation in the classroom problem solving exercises raised questions of student engagement that were evident in the participation rates.

There is also some question as to whether the use of the *Educosoft* software is a sufficient replacement for the guided student practice and independent work components of a high quality behaviorist model of instruction. However, without student participation in the classroom demonstrations of solving the problems, it is not clear how students could become engaged by the software alone (or supports provided in the math lab). There is, however, evidence that providing examples of solutions to well defined problems helps students in mathematics learn the problem schema (Jonassen, 1997):

> Several comparison studies of worked examples and trial-and-error problem solving in the domain of algebra showed that studying worked examples was more beneficial since the standard means-end problem solving strategies used by novices impose a heavier cognitive load than worked examples (p. 76).

Using worked examples can help learners to “categorize problems with similar solutions and construct solutions to novel problems by analogy to the example” (p. 76). Jonassen also suggests that working out examples not only models how the problems are solved but provides a description of the thought processes involved in solving the problem.

Because students see the instructor modeling increasingly complex but well defined multi-step problems, they are able to see how a worked problem is solved where: a) answers were not obtainable from direct application of formula, b) problems encouraged developing a formula that fit the textual presentation of the problem, and c) involved problems that required use of concepts/skills learned previously (converting percentages to fractions or decimals).

Once students had completed the math at Tropical College, they could take the introductory courses in their program of study. Regardless of the effectiveness of the instruction, the requirement for delaying entry into a program of study for too long can add barriers to completion for developmental students. Jenkins and Cho (2012) reported how critical it is that students enter a program of study as quickly as possible. They state: “Students who do not enter a program of study within a year of enrollment are far less likely to ever enter a program and therefore less likely to complete and earn a credential” (p.3).

Some of the ATE faculty we interviewed at other institutions suggested, however, that even when students went through the developmental courses successfully, they still could not do the applied math in the introductory ATE courses. A number of faculty spoke of innovative strategies they use to help students acquire the math necessary for their program. The majority of program PIs contacted, however, depend on the traditional pathways using prerequisites and student supports through mathematics and into ATE programs for their students and program completers.

Getting students into rigorous ATE programs after high school is one of the first problems PIs talked about. The East Coast Center PI (ECCPI) reported that a recent study showed that annually 800 new technicians were needed in a single specific occupational area. Yet, the 35 colleges in their network were producing less than 300 completers. He characterized the problem with "the most important thing we can do is get the enrollments up and reduce their attrition." When programs cannot attract students and keep students who are underprepared the institution often terminates the programs. A number of PI's reported that they were not only doing outreach in high schools, but also revised curriculum to address multiple technician areas to address the low enrollment problem. ECCPI reported:

> … So if they've got a specific program, that's, that's a special instructor, labs somewhat, and they got 12 people in that program enrolled in it. They'll cancel it. We had to go back and restore six programs that had been stopped. And we found a more, we found a strategy that will allow colleges to do this much more efficiently, cost wise, and it also addresses a need which emerged very recently in the country for what we call inter-disciplinary technicians or systems technicians. Whereas 20 years ago, we thought every laser technician needed eight to ten courses in lasers which are taken from a faculty member in [the program]… and two or three million dollars of equipment.
>
> Now, we're bringing all our colleges back down to where they're teaching three courses and it's built on an electronics core which also leads to robotics and other things to spin off of -- and so now it takes one faculty member. We're going to get the total cost of this thing down to under $200,000 of labs. And it is going to make it much more easy for them to do. The other problem is though, is identifying and interesting and recruiting and preparing these students while they're in high school.

Interesting students in ATE careers, recruiting them and preparing them while they're in high school was one of the East Coast Centers initiatives. Dan Hull, in his book Career Pathways for STEM Technicians (2012), describes the difference between high school STEM programs for professional scientists and engineers, such as Engineering that includes Engineering Design theories and in those designed for the technicians in those areas that are needed. He cites the need for "qualified technicians and skilled stem workers in advanced manufacturing, utilities and transportation, mining, and other technology-driven industries" (P.v.). While high school programs that prepare students for Bachelor of Science degrees are needed, the "calculus and pre-calculus courses become a filter that screens out students who are not interested in or successful at abstract math" (p.4). He argues that those screened out students are more hands-on learners with good spatial abilities but without an applied learning pathway, "they drop out - physically or mentally" (p.4).

Nathan, Atwood, Prevost, Phelps, & Tran, (2011) in their article "How professional development in Project Lead the Way changes high school STEM teachers' beliefs about engineering education" discussed their study of how teacher's beliefs influenced their instruction:

> Teachers generally believed that to become an engineer, students must show high academic achievement in their science, math, and technology courses. Teachers also believed, on average, that having a parent as an engineer increases a student's likelihood of becoming one, as does being male and either white or Asian. (p.16)

Nathan et.al. argue that these beliefs focus rigorous STEM curriculum on mostly high achieving male Asian and white high school students. ECCPI characterized the STEM high school problem as:

> Their attracting the top 20% and that's all they've been looking at. I mean there are few exceptions, but almost without exception they're trying to [teach to] the top 20%. Their putting through a curriculum which the first two years isn't too bad, it uses something called Project Lead the Way. It's a good curriculum. But the last two years, I mean you've got to have calculus, you got to go on to Engineering Designs theories, and everything else. So it's not appropriate for the technicians… we need to go back and get these STEM high schools to not do anything different from what they were doing but add a pathway for these students that are below the 20%, the ones that looked like they have good potential to be technicians. And we've identified some things to do it.
>
> And then to change their curriculum in the last two years to focus them toward community college and prepare them for the work they've got to do…. we did a model and then I had eight other national centers show the curriculum model that would work to do that. This is taking place very slowly as you might imagine.

The ECCPI also suggested that creating an alternative high school pathway for students that would lead to occupations as a technician was not enough. Some of the colleges in his network had added a program specific recruiter that went out to their feeder high schools. One program had declining enrollments over the prior 10 years, from more than 150 students to only 40 students. That program more than tripled enrollments after three years of program specific recruitment to over 185 students (Panayiotou, 2008).

The program recruiter's work included biweekly visits to ten area high schools and the workforce retraining office where the recruiter:

> … meets with students, counselors and teachers. The students showing interest in the program are assisted and guided through the college application process, taking the college placement test, and applying for scholarships and financial aid. The recruiter organizes monthly information sessions for prospective students and their parents. During these sessions the department chair explains the RPI, the type of employment available to graduates, the future outlook and salaries, and then gives a tour of the labs. A special open house for high school seniors is organized every year during the fall semester, and an evening open house for students and parents is typically organized in the spring semester. During the summer semester a one-week summer camp in emerging technologies is offered for high school juniors and seniors. (Panayiotou, 2008, p.6)

Hiring a program specific recruiter more than doubled their enrollments in the first year (40 to 105 students). Panayiotou (2008) also reports that "Hiring a dedicated part-time recruiter is the most effective way to ensure continual and steady student enrollment. The revenue from just two new full-time students will more than cover the cost of the part-time recruiter" (p.9). ECCPI had an interesting perspective on hiring program specific recruiters that relate well with high school students:

> They took that grant money and they hired a dedicated recruiter, it's hard to get colleges to do a dedicated - a lot of colleges say "we'll get our recruiter to go out to high schools" [but] they talk about everything the college does and that doesn't work.
>
> The other thing that we found doesn't work is to send a 40 or 50 year old or older faculty member out there. If I went out there, they'd think "it was my grandfather talking or something." What they did is they hired a woman that was 22 years old who had a marketing degree and she had a small child at home. She wanted to work four, five hours a day and she'd work for practically nothing, just because she wanted to stay on board. And so they hired her … and they brought her in and gave her two days orientation about what Photonics and lasers and optics was and they sent her out to the high schools to strictly recruit for Photonics.
>
> And then she'd come back each Friday - I mean this woman couldn't spell laser when they hired her - and she's come back each Friday and tell us what they asked her that she couldn't answer. After two Fridays' she didn't have any other questions, she was

> well on top of everything the high school kids wanted to know. So they had her in, working for about five hours a day, four to five hours a day and she turned that program around. That program was almost ready to go into the tank. And she got it to where in two years it maxed out … they're teaching day and they offer courses at night and other things.

ECCPI also argued that recruitment early in high school helps students focus on appropriate pathways and courses. A number of colleges in their 35 college network offer dual credit to start the program early enough to engage high school students.

> …for the ones that are nearby, within about 30 miles of their college, they have worked up dual credit programs with them. And these students take courses on the college campus. I think dual credit courses will work either way, they can take them on the high school campus where they will train the high school faculty members to do that there. And they've got to have equipment.
>
> The good thing about having them take some of these courses on the college campus, many of the students that are in this situation are coming out of families where their parents may not have a college education. They don't have the confidence that they can be successful in college and they haven't been on a campus. If they can enter into this dual credit course they can take that. Then they can see that they can do college work and they could find out they like the environment and they're more motivated. So they're on average -- their dual credit programs are providing between 15 and 30 dual credit hours for these students coming in. A lot of them come in and finish one more year and they're gone.

High schools need both professional degree and technician pathways to help the applied learners prepare for their college education as do the community colleges that receive them. Otherwise, if ECCPI is right, and the 80% of students who come to the community colleges are those who dropped out physically or mentally, then placing students into the same type of professional degree and technician pathways, requiring high levels of prerequisite math that do not support applied learners will not address the completion crisis.

Using prerequisites in pathways does not necessarily suggest that pathways and degrees are standard across the states or even institutions within them. Additionally, while some states only have Associate in Arts degrees (AA) and state recognized certificates, others have AA, Associate in Science, Applied Associate in Science degrees, and a multiple levels of certificates including state and locally recognized. Prerequisites can differ, as will be discussed, not only for degrees and certificates, but also for majors within those categories. And, many faculty and administrators, as we found, may not even be aware of those pathway possibilities at their institutions.

Western college is a good example of targeted prerequisites for majors and degrees and an example of departmental isolated knowledge of contextualized prerequisites. A group of administrators interviewed showed how each administrator had different parts of the institutional pathways in their responses. The dean of sciences for example stated:

> …So if you're looking into the sciences and the health sciences - those programs are pretty much tied to a college level prerequisite mathematics because you just can't be successful in those areas if you have less than college readiness in math or English and so the prerequisites of those classes are pretty standard as they are across the country.

That same dean of sciences immediately started adding program specificity to the college level math offerings:

> If you get into the health sciences careers we have a variety of different levels of math that the students have to prepare for. For example, within nursing they utilize what we call college level math, math 120 or 126, which is either math for liberal arts which adds the statistics components by the way. That's why they like that, and then also the traditional pre-calculus which we call math 126. Almost all the programs have that. There's one exception and that is the dental assistant program which has an embedded math for their certificate and then a health careers math for the prerequisites for their degree program.
>
> The career tech which is what [the CTE dean] has - we have a typical occupational technical math that those students qualified for and then there's some specific math, those specific areas and he can talk about that. So their movement is more toward embedded math simply because the pipeline is so long that it's affecting the graduation rates. So that's the direction that we're headed there.
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> … If you look at the math for the occupational math we have classes like geometry. We have a real estate math. We have a math for allied health. Those particular classes are offered on almost a one on one basis. The students will combine because we didn't have enough students to create a full section so we combine them all and one teacher will work students through. It's a workbook format where they take one on one instruction from an instructor and work their way through the content and that's works very well. A lot of those students are the ones that feed into, like I said, the allied health program. And then you have some math like culinary has their own math but those are pretty much occupational based.

The CTE dean added that those content area math classes, math designed for specific programs, only fulfills the requirements in their respective certificates or AAS degrees.

A few of our respondents reported that even students who had completed prerequisite math courses were unable to transfer that abstract learning to an applied situation. East Coast Center colleges found that math needed for program success was often a barrier to student success in their programs for many students meeting prerequisites. As ECCPI put it:

> … we had one of our colleges, it was losing 60% of their students because of Math deficiencies, the first year… We've converted our text materials [on our first two program courses] to an e-book… we went in and analyzed the material and found the 11 Math concepts that they have to know to learn this.

Some East Coast Center colleges collaborated on a way to help students transfer abstract learning to an applied situation. They started with a supplement to Math materials in their first course. In that book, they identified 11 math concepts in the context of light and lasers using problem based learning. Those supplemental materials have evolved as they converted the text to an electronic format.

> And so what we did is develop Math video tutorials on these concepts. We went back and reviewed the concept and then [have them] work four or five problems. So they get along in the e-book and they get up to a point and they can't work a problem unless they know how to use the Math concept of ratio and proportions. And there's an icon and it says "You need help?" So they click there and this video comes up. Well it's kind of just in time Math for them but we have taken – it's gone from 60% attrition down to 0% because of Math.
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> We need Advanced Algebra. We need Trigonometry, we don't need any pre-Calculus or Calculus. We need the same thing electronics needs, I mean they've got sinusoidal motions, they've got to know wave motions, they've got to have good Algebra and Trigonometry. (ECCPI)

In that evolution, they developed a pretest that some colleges used to identify students at risk of not being able to use the math necessary to solve problems in the program courses. Then, using a form of just in time learning and supplemental instruction, instructors could help students succeed in the math problems needed for the course. ECCPI contributed an example from one of the colleges:

> Gary could then look at all of these students and figure out where their deficiencies were. Each student had a copy of this Math for Photonics Technicians. And when Gary would go along he said “Okay next week we’re going to study a certain topic. If you don’t know sinusoidal functions, (I always use knowing ratio and proportion just an example really), if you don’t know this concept, you’re not going to do well in it. So you need to go to chapter six in this book. And review this work and work these problems at the end.
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> And then he said “Now there’s six of you, I’d like you to come by my office on Thursday afternoon.” Those were the six that did really poorly in it. He said “come by my office on Thursday afternoon.” And he sat there and he goes over this stuff in person and emphasized it to let them know that he knows that this is a topic they’re struggling with. This is the guy that went from 60% to zero in attrition.

One of our respondents at Southern College also suggested that often students who had completed the math sequence before entering their engineering program “just had never used math to solve an engineering problem and couldn’t put the problem solving math tools they learned in the abstract together with real engineering problems” (Southern College faculty). They found that students, who were assessed into their developmental prealgebra course, were more successful if they accepted them directly into an introductory program course with applied math topics. As we heard from many colleges, however, they told us that they could not call it a math class or else the Math department would have to teach it.

> So, we couldn't call it Math, so what we call it is Introduction to Engineering Technology. We started it as EET 100 which EET is the prefix of all our Electronics courses. Well, when the other programs found out what we were doing, they asked if they could participate. So what we did we developed a class further to include areas in Mechanical Design, Civil Engineering Technology, Machine 2 Technology. So, we cover all the Engineering Technology areas and teach the Math that’s needed in each one of those areas in this course. And, we’ve just seen a big difference in the success rate (Southern College faculty).

The evolution of the course at Southern College was just as telling. Instead of losing students in both the developmental math sequence and the introductory ATE course, they found they could have high pass rates in the intro course and help students develop high level math skills needed for their program. And, those students could then pass the math course needed for graduation.

> …what we learned a few years ago, like everybody learned, was that the majority of the students coming into our area, which my area is Electronics Engineering Technology, just about all the students, or a large majority of them, have to take remedial math and they would take the remedial math. They would come in the first Electronics class and we still have probably 50% that dropout. And that pass rate, that just wasn't really acceptable. When you would just work with the students, you would see that the math skills were just so poor that they couldn't work basic high school problems in like algebra or trigonometry. They just absolutely couldn't do it.
>
> So, you know, we sat down and looked at the problem and said, "Well, what we need to do is come up with a course, a first course where we teach just the applied math they need to get through the program." So, we sat down and we identified where the weaknesses were and we found a book called "Mathematics for the Trades." And so, we went through that, picked out what we needed, added what we needed, and we've been doing that here for probably the last 15 years, and now in my first Electronics class, the C-pass rate and above is probably 80 to 85% now.

Southern College also believes that students who complete their introductory course with applied math topics and then take or retake the math assessment test, place into college level math (required for the degree) and are no longer are required to do the developmental math sequence.

> …we found it to be the case that most students that come in and take this first class that we developed, they'll go back up and either retake or take the math placement test after having this class (which doesn't have a math placement requirement). And they'll go up there, then they will qualify for College Algebra, Math 100. So, they don't even have to take remedial classes, if they take this one first, if they take this applied math class first.

At Western College, the faculty in ATE programs created a math course for civil engineers by selecting specific topics that included most of the elementary algebra topics and some right angle trigonometry from pre-calculus. They also embed math in many of their courses as suggested by the dean. A Western College faculty respondent, interviewed separately, recalled a statement from a recent engineering professional development trip of "…the fellow's talking about Math [and] he said 'We embed Math.' He says: 'Math is too important to leave up to a Math professor.'" When questioned about the level of program courses they embedded math in, he responded:

> Well, it's just part of the engineering courses and … maybe the students have got to a certain level… You're going to have to teach that because they haven't had statistics. So you got to give them enough statistics to get through this course for their "material behavior" but it's not something you have to teach them all statistics... like I say, you don't need to know the equation for the ellipse if you're going to do just basic Math…there's a certain idea that everybody ought to have math and its good for them … The Math that these folks are required to have is just not that, what would I say, not so complicated that you can't embed a lot of that.

The western college engineering faculty recalled how his experiences as an engineer helped him develop some of the engineering programs and courses offered at the institution:

> I used to own a company in town and there was always a room for Civil Engineering practitioner. Kind of like a paralegal, a little bit higher up than a technician, more education than a technician yet not a registered engineer. So with that I looked at the college degree that we offer, Associate in Science degree in Engineering, with an engineering emphasis. And basically that's the first two years of an engineering degree. You should be able to walk in to the university as a junior with that Math and Science, basically your core courses.
>
> ... So what I said was most practitioners really don't need Calculus. They don't need Differential Equations. So we took the curriculum which had four semesters of Calculus including Differential Equations. We pulled those out and replaced them with a College Algebra requirement. And then backfilled those courses, those extra courses with a lot of practical courses. …So we've put in courses like Case Histories in Engineering, Little Mechanics, Hydraulics, Hydrology, Introduction to Engineering Economics, Materials Behavior, Statistical Analysis.
>
> And we've developed courses around those, we developed Algebra based courses with those, to those different courses. And then we've put in Construction Planning and Construction Law and Construction Document Specification. So this was going to build an Associate of Applied Science or Civil Engineering practitioner.

Because faculty in the department saw the increase in student retention and success, and because they held monthly meetings where they discussed student success and curriculum, they decided to implement those ideas in other programs. He spoke of another program they were embedding specific math functions into:

> … we started another program here… We have a lot of geo-thermal energy here and a lot of power plants. We've got about ten geo-thermal companies in town here. And so we decided to setup a geo-thermal plant operators program. It is a certificate of achievement which is 34 credits. Now they're getting into some more math there again

> and it's more direct approach mechanical engineering, thermo-dynamics and things like that... Same math skills but different applications.

Like Southern college, Western College also has created a more general math for technicians and math for other technical areas that they use for a number of their technical certificate programs. Also important is that the prerequisites are specific to AA, AS and AAS degrees and certificates and importantly majors within them. They also have developed skill certificates, not originally recognized by the state, but that now count for student completions. The Dean of Sciences at Western college recalled:

> …In many of the career tech programs however, the students simply don't take the math classes … required to obtain the degree and subsequently they don't graduate from the programs.
>
> But they are… we discovered that they're adequately prepared to get through the sequence of the courses with the math that is taught in the courses because of the applied nature and the student's ability to understand how the math is working in that particular situation.
>
> So we've developed skills certificates that are now recognized by the state, thanks to our Associate Dean [here], that acknowledge even though those students have not completed a degree, they have obtained their goal that they set for themselves when they entered the college. Therefore they should be counted as completers.

In fall 2014, Connecticut will begin a large scale implementation of just these types of embedding math into introductory courses. A 2012 law (Public Act 12-40) requires Connecticut public colleges to embed remedial education in credit-bearing "100" courses, with tutoring and support assistance for students who need remedial help (Inside Higher Ed, May 7, 2012). As the 2014 implementation looms amid numerous complaints of feared access limitation and concerns over students being unable to catch up in normal college work, the Connecticut community colleges and State Universities have piloted 136 classes following the new model (Thomas, 2014). Jaqueline Thomas reports in *The CT Mirror* that the president of Eastern Connecticut State University, Elsa Núñez, told their legislature's Appropriations and Higher Education committees that access to college had not changed. "We are not turning anyone away…We are turning remediation on its head with this." Núñez also reported that the results from the pilots show that "We didn't do worse in this model than in the previous model we had" (Thomas, 2014). Whether a whole state system can be scaled up to include some of the innovative ideas we found in ATE programs will be an interesting experiment.

A number of ATE program college respondents in the Pipeline to Pathways study also reported that introductory course faculty were using project based learning to make the math relevant for students. At Western College, which had a project-based learning center, an engineering faculty spoke about the many ways faculty had integrated project-based learning into their programs:

> … we have student competitions… I'd have them build a bridge, a truss basically and then we load it and see the, look at the load to weight ratio, and the guys that had the lightest truss with the highest strength would always win. That was the deal. So that was, it's a truss and you couldn't spend more than 20 bucks on it and it had to be built of balsam wood and glue.

Another faculty he mentioned revised the Engineering 100 curriculum to start with project-based learning: "…the Engineering 100 class has changed from electric class to the first thing the students do is they sit them down and they design and build a hover craft. Little hover crafts…And then have hover craft races around campus." Another project-based learning session for the Engineering 100 class from a different faculty started with students building a little robot that used syringes and tubes that moved this arm and claw around to pick up a block and move it to another spot. He then had the students write directions on how to pick the block up and move it with all the syringes recording how many cc's of water were moved through each syringe to move the arms. Then he would "have the other team come in and follow their directions to see if they can do it."

Students were not only engaged in the courses with this type of project based learning, they also understood the relevance of the math and the importance of accurate measurements, calculations and recording them. Throughout the interview, it was clear that the Project based learning center grant had influenced curriculum development. More importantly, the department faculty monthly discussions of curriculum and student success helped the faculty tryout project-based learning ideas and share whether they saw increases in student success on a regular basis.

Still needs to be wrapped up, problems in mainstreaming innovations added and a conclusion section developed

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