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Demonstrating a Continuous Improvement Process in Action with an Initiative to Adopt Computer Algebra System Calculators in an Engineering Technology Degree Program

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Any ETAC of ABET accredited engineering technology program must have a documented process for continuous improvement, must show that this process is used, and must show results from that process. At the baccalaureate level, ETAC of ABET accreditation criteria require that the curriculum include the use of differential and integral calculus. This paper presents an initiative in the author's department to improve student performance in the use of differential and integral calculus. This effort also demonstrated the department's continuous improvement process in action.

Students are expected to learn differentiation and integration in a required calculus course, followed by additional instruction in an upper level major core course. Students are expected to be able to find derivatives, including ones requiring use of the chain rule, and to solve integrals, including ones where substitution is necessary. This has been done by hand using printed lists of rules and lists of integral (anti-derivative) solutions. Over time, student performance has been less than satisfactory. Efforts made to improve performance have produced disappointing results.

Computer algebra system (CAS) calculators capable of performing symbolic operations including differentiation and integration offered a new option. The author proposed that the department change to an approach based on the use of CAS calculators for calculus. Adoption of the CAS calculators would be a substantial change to the curriculum. Instead of attempting to teach students to do this work directly, they would be taught to use the calculator. This would leave students dependent on a CAS calculator for calculus. However, students should then be better able to use calculus when needed. This proposal was discussed by the faculty, resulting in an agreement to further explore this option. Moving forward, the department sought input from constituent groups. Input was sought from the department's Industrial Advisory Board as representatives of employers of our graduates. Surveys were used to get input from alumni and from current students. With support from all constituent groups, albeit with some reservations, the department adopted the CAS calculator proposal. Based on exam results from specific classes, student performance has shown a marked improvement.

From assessment and evaluation activities at the course level to efforts to get the opinions of current students, alumni, and employers, this effort showed the department's Continuous Improvement process in use. This paper will present the initial situation, the proposed change, activities leading up to the decision to adopt the CAS calculators, and the results. Assessment and evaluation activities and results and the Continuous Improvement process will be discussed.

Introduction

On page 9 of the 2023-2024 Criteria for Accrediting Engineering Technology Programs, under Criterion 5 – Curriculum, the following statement appears:

> Baccalaureate degree curricula will include the application of integral and differential calculus, or other mathematics about the level of algebra and trigonometry, appropriate to the student outcomes and the discipline [1].

If a department offers baccalaureate degrees in the area of electrical and electronic engineering technology, the criteria for that area states that

> The ability to utilize differential and integral calculus, as a minimum, to characterize the performance of electrical/electronic systems

is a requirement for the curriculum [2]. Differential and integral calculus is also required for programs in mechanical engineering technology [3].

In the author's department, the Department of Engineering Technology at Austin Peay State University, this has long been addressed by a requirement for all students to take one course in calculus by the end of the 2nd year, followed by a course intended for 3rd year students that included calculus as one element of the course content. The use of calculus has also been required in other courses, including a course in thermodynamics taken by all majors.

Initial State

Despite efforts to improve performance, student performance with calculus in the upper level course was consistently poor. While some students demonstrated solid knowledge of the material, others did very poorly. After the required course in calculus, students should have come to this course with the ability to demonstrate basic knowledge. Instead, even after intensive instruction, homework, and midterm exams, some students still did not demonstrate basic competence on the final exam. Some were fortunate indeed that the course had other major components, so that they could pass even with poor performance in this area.

The author has long been the instructor for upper level courses which includes calculus content and has tried without much success to improve student performance. As the author belatedly became aware of the new technology of CAS calculators, it seemed that adopting these tools could be the key to improving performance in this area.

Since engineering technology focuses on applications, our primary concern is that students and graduates be able to use the basic tools of calculus. If presented with a problem requiring them to find a derivative or the solution to an integral in one dimension, students should be able to find a solution. If learning how to use the CAS calculator gives students this capability, then it would meet our goals. This may not be acceptable for an engineering degree program, but it is sufficient for engineering technology.

This upper level course is a course in problem-solving in engineering technology, and it should not be heavily focused on mathematical problem-solving. When the course was added to the curriculum, circumstances had forced the department to make changes to the calculus requirements, and this course had to include content in calculus. While tools used in problem-solving are covered, the intended focus of the course is on the broad picture of problem-solving. Problem-solving in engineering technology is not just solving math problems, and too much class time spent on calculus sends students the wrong signal. Adoption of CAS calculators held promise of reducing the time needed for calculus in this course, and would allow more time to be spent on aspects of problem solving in an engineering environment.

Computer Algebra Systems in Engineering and Engineering Technology

Computer software allowing people to perform symbolic mathematical operations has long been available for personal computers. Products such as Mathematica from Wolfram Research [4], MATLAB from Mathworks [5], MATHCAD from PTC [6], and MAPLE from Maplesoft [7] have been available since the 1980s. In a white paper sponsored by Maplesoft, Lopez discussed early efforts integrating CAS software into calculus courses at Rose-Hulman Institute of Technology [8]. In this document, Lopez gives a story of promise frustrated by the limitations of the software in the 1990s; improvements made over time have made CAS software far easier to use [9]. A major advance has been to add CAS symbolic math capability to engineering calculators [10]. With that innovation, CAS could be required based on students having a calculator in the $150 price range, rather than a computer loaded with the CAS software. Plus, the instructor could allow the use of the calculator without allowing students to use a computer that would allow greater opportunities for cheating during exams.

Over time, faculty at many institutions have sought to bring CAS technology into the curriculum. This has resulted in a substantial body of literature; [11-27] are representative of this large body of work. This body of work included application in calculus and other math courses and in engineering and engineering technology. These efforts included lower and upper level courses and courses in different areas of engineering [11-27].

Most efforts surveyed made use of CAS software installed on computers. MATLAB [17, 24, 25, 27], Mathematica [14], Maple [22], and other software was used. For quite some time, computers were the best (or only) platform to take the place of pencil and paper for symbolic mathematics. This required either the use of a computer lab or laptop computers. Use was therefore limited by the need to have students work and take exams either in a computer lab or with laptop computers. Either the institution would need to supply computers loaded with the software or the students would be required to purchase both computers and software. During exams, it would be impossible to restrict the students from using other features of the computer – features that could be used for cheating.

The CAS calculator offered a new option. Students could use CAS technology without the need for them to have more expensive and more capable devices. The CAS calculator technology would be something they should be able to use well past graduation.

Comparing these efforts to the perceived need in our curriculum, most of the work surveyed was focused on the requirements in mathematics for engineering, instead of engineering technology, degree programs. Math at the level of multivariate calculus and differential equations was a major concern. Students were expected to use CAS software loaded on computers.

The goal of this work is to meet more modest needs. In our curriculum, students are expected to do mathematics with a calculator, and not with a computer. The curriculum includes calculus as required by ETAC of ABET [1], but does not require calculus to the depth required for engineering. The needs of our students are met with tools to evaluate derivatives and definite integrals in one variable. As opposed to the work reviewed where more sophisticated tools are needed, calculators such as the TI-Nspire CX II are a better fit to the needs of our students.

Proposal to Adopt CAS Calculators

The author proposed that the department should require students to purchase TI-nspire CXII CAS calculators, and that we should then allow students to use these calculators for coursework, including exams, in most classes. The primary reason was to improve student performance with calculus throughout the curriculum and after graduation. Considering this proposal would have a secondary benefit: it would give us an opportunity to demonstrate and document our continuous improvement process (CIP) in action.

IF the proposal was accepted, this would mean a change in what would be expected from students. For example, the author has long expected students to make some use of calculus in thermodynamics and dynamics, which would document use of calculus in the curriculum as required for ETAC ABET accreditation. The author has expected students to use lists of rules for derivatives and integral solutions from tables, and to use the chain rule for derivatives and to make substitutions when using integral tables. If the CAS calculators were adopted, instruction in calculus would change from the traditional approach with rules and integral tables to the use of CAS calculator technology. Looking ahead, this held promise that students would have a better chance of being able to use calculus if needed after graduation.

Also, with this change, the use of calculators would be standardized across the department. At the time this proposal was made, some instructors already allowed their use. Only some students had the calculators; those without were at a disadvantage. Finally, the department serves many students who receive Veterans Administration (VA) and other benefits. If a tool like a calculator is required for a course, then their benefit package often covers the cost. Making this a requirement across the department would mean that all students should have the same tool with the CAS features, and that, for some students, the cost would be covered.

In the process, the proposed change gave us an opportunity to demonstrate our continuous improvement process (CIP) in action. The department's process requires us to seek input from constituents and consider this input in making decisions. By going through the process of reaching out for and taking input from constituents into account, we would give a set-piece demonstration of our process.

In short, this change promised to improve student performance with calculus, to help students do the work in courses requiring calculus, and to allow both student and instructor to focus on the primary course content instead of on how to solve calculus problems. On graduation, having learned to use this new technology to improve their productivity, students would be better prepared for the workplace. It would also let us demonstrate our CIP.

Benefits and Concerns

Allowing students to use CAS calculators had both positive and negative aspects. The negative aspects are similar to concerns over allowing the use of the then-new electronic hand calculators during the 1970s. Going into the 1970s, in trigonometry students would be taught to use tables – tables of values for trigonometric functions, inverse trigonometric functions, and logarithms of these functions. Students needed to become proficient in linear interpolation, the use of logarithms as an aid in multiplication and division, and other aspects of calculations and of using data in tables. With affordable scientific calculators coming out by the mid-1970s that allowed you to multiply or divide numbers and to find the values for trigonometric functions with a few clicks of the keys, a student who had one of these calculators no longer needed to use the tables.

At that time, the pluses were that students could perform calculations quickly and more reliably using the new technology. The minuses, however, were that students would not learn to do this work without the calculator. They would not learn how to use tables or how to use logarithms. Perhaps more importantly, if a student was to go on into an area of engineering where they needed to use tables, they did not learn how to do this in the trigonometry course. For example, students taking thermodynamics need to know how to use tables of thermodynamic properties. No longer would they develop that skill in a previous course in trigonometry. Finally, the calculators were expensive. Those with families who could afford the calculators could do work far faster than those who could not buy calculators.

The author observed as his father dealt with this issue at the high school level, where he taught trigonometry and calculus. At the time, his solution was to allow the use of basic, four-function calculators. These had become relatively inexpensive, and it was reasonable to expect students to purchase them. Students would have that aid for addition-subtraction-multiplication-division, but would still need to learn to use tables. Having those skills helped students who went on to work where they needed to know how to use logarithms, tables, and linear interpolation.

CAS Calculators

With the CAS calculators, the pluses are similar. With the CAS calculator, people can perform calculations faster and more reliably. To find a derivative or to find the numerical solution for a definite integral, someone using the calculator can get a solution with selecting the option on the menu followed by a few clicks of the keys. If students would be allowed to use these tools on the job after graduation, then using them while taking courses would better prepare them for employment.

However, some things are lost in this process. The student does not learn how to do this work without the calculator. Solving a calculus problem by hand requires students to use algebra and may also involve trigonometry; this practice helps reinforce their basic skills in mathematics. The basic tools of calculus are used in derivations of relationships used in engineering and technology. If a student understands calculus, they are better able to understand the work behind the results, how to use the results, and the limitations of the results.

Also, these calculators are expensive. Some students will have difficulty paying for the device. Further, in courses taught by the math department, students are expected to have and use less-capable calculators. This may lead to a student having to purchase two calculators. This is a concern, but the costs are such that it should be feasible for students.

The question of whether to allow the use of CAS calculators in classes comes down to whether the failure to develop their knowledge through working problems manually would leave the students poorly prepared for careers after graduation. If they can plan on using CAS calculators at work, can do the work faster and more reliably with these tools, and can retain this ability longer, then we should allow their use.

Consideration of the Proposal – Seeking Input; Revisions Made Due to Input from Constituents

As part of Student Outcome Evaluation and Assessment in 2020-1, the author examined a performance indicator (PI) covering calculus from the upper level problem-solving course. Results were collected from the upper level problem-solving class for a section taught in Fall, 2019. As documented with a standard department PI assessment and evaluation form in December, 2020, the results fell below the department standard, requiring action. Following an earlier department practice where data from major core courses was not segregated by concentration, this represented performance in all concentrations.

With the PI results requiring action, the author then prepared a proposal for action. This document included the PI results, a review of options, and a recommendation for action.

Proposed Action: Consider requiring and allowing students to use TI calculators with CAS (Computer Algebra System) capability to perform symbolic operations including calculus.

This document also included a list of steps to take to seek input based on the department's CIP as follows:

Faculty

- Is this acceptable to the faculty? This is primarily an issue for the full-time faculty
- Input: discussion in regular faculty meeting

Industrial Advisory Board

- Will this be acceptable to companies who employ our graduates?
- Input: discussion at IAB meeting and documented in meeting minutes

Alumni

- Based on their experiences, will this be acceptable in the workplace?
- Input: Alumni Survey via online survey tools

Students

- Seek comment
- Input: Student survey via online survey tools

The first constituent group to consider the proposal was the faculty. Preliminary discussions took place at times during regular weekly faculty meetings during the 2020-1 academic year.

Following these preliminary discussions, a formal proposal was presented and discussed during the department faculty meeting on April 23rd, 2021. In discussions prior to this meeting, it came out that some faculty members were already allowing students to use these calculators. After discussion, the faculty voted to move forward with this proposal.

Next, the department sought input from other constituent groups: industrial employers through the department's Industrial Advisory Board, alumni, and current students.

As representatives of companies in the region who hire our students and graduates, the department sought input from our Industrial Advisory Board (IAB). With the IAB, the department used surveys as well as discussions in IAB meetings.

The proposal was presented and discussed at an IAB meeting on April 30th, 2021. A separate set of minutes covered this part of the meeting. The question put to the IAB members was this: would industry needs be met IF we moved to requiring calculators that automate the process of symbolic solution necessary for performing calculations requiring the use of calculus.

The responses were summarized as follows:

- Students still need to have some experience learning topics in mathematics by doing the work themselves instead of using a calculator. To some degree doing this work without the calculator needs to stay in the curriculum.
- With that, the IAB supports the department in moving to the use of CAS calculators where calculus is used in engineering technology courses.

Specific comments by IAB members (not faculty) included the following statements:

- Knowing how to do this work by hand is important. After that, then go to the calculator.
- Knowing is important – but it is appropriate to use the calculators.
- For engineering technology as opposed to engineering, focusing on the use of calculators for calculus is acceptable.
- In the construction field, he (this IAB member) has not needed to use calculus on the job. There is value in being able to do the work by hand.
- While it is better to have more knowledge, the ability to use modern tools is also good.

The department responded as follows:

- **Modify proposal based on IAB response:** students will still be expected to learn traditional means of solving calculus problems without a calculator. This may be covered during the calculus course.
- The department would proceed with this proposal and will consult students and alumni via online surveys. The faculty will then consider the responses from all constituents before reaching a decision. IF accepted, action will be taken starting in Fall, 2021.

With those modifications, the final consensus that the department …

i) should move to the use of CAS calculators for work where students need to use calculus in engineering technology courses while

ii) **having students learn to perform calculus operations by hand before moving to the calculator; this can be done in the required calculus course.**

was approved unanimously by the IAB members present.

The process continued with seeking input from alumni and from students. This was done using online surveys through SurveyMonkey. We received enough responses from both groups to give us useful feedback.

Alumni: from the alumni, we received 22 responses covering all concentration areas.

Respondents were given five options on a Likert scale from Strongly Agree to Strongly Disagree. For the summary given here, this has been reduced to three options.

Summary of Alumni Survey Results	Agree	Neither	Disagree
Q1: Respondent Understands Role as Constituent in Continuous Improvement Process	21	0	0
Q2: When using mathematical tools - algebra, trigonometry, and calculus - you work with symbols, following rules to rearrange or process symbols, and you work through the numbers. After you spend some time working with the symbols by hand in math courses, should we have students use Computer Algebra System (CAS) calculators to do the symbolic work as well as crunching the numbers?	16 73%	2 9%	4 18%
Q3: We are considering having students buy a CAS (Computer Algebra System) calculator in the $130-$160 range that would help them do better in engineering technology courses. This could not be used in MATH 1530 Statistics (a required course) or other math department courses; students would have to have a different calculator for use there. We know it is a burden for students, but we think students can afford this and it will be worth it to them when using math in our courses.	18 82%	3 14%	1 5%
Q5: At work, I can use a calculator any time I need to use math on the job.	22 100%	0	0
Q6: At work, I should use a calculator to do as much of the math as possible to save time and avoid mistakes. The more I can do with the calculator, the better.	19 86%	3 14%	0
Q7: IF I had been able to use a calculator to do the symbolic math when I needed to use calculus, trigonometry, or algebra in engineering technology courses at APSU, it would be better and easier for me to do that work now.	12 54.5%	5 22.7%	5 22.7%

Alumni comments, copied from the surveys, included the following. To avoid altering the content, the use of pronouns and other aspects of the language used has not been changed.

Q2: Should we have students use CAS calculators?

I think having a fundamental understanding, same as students have in algebraic manipulations, is very important for flexibility in applications.

They should learn how to do it without the CAS, then be allowed to use it for faster results.

Yes, Basic is important, but when you are working with large amount of computation knowing your calculator is best.

I believe that teaching the fundamentals is needed before a CAS is allowed. After the student is tested using only traditional means, should a CAS calculator be introduced.

The CAS calculator is a crutch. How are engineers supposed to learn calculus and other mathematics if all they have to do is watch a YouTube video and press of a few buttons?

We need to focus more on applications of calculus rather then [sic] spending extra time solving calculus problems by hand. I agree learning the core fundamentals by hand is beneficial but it overall slows down the conceptual understanding of when and how it should be used.

I used the ti-nspire [sic] when they first came out. I highly suggest them.

I agree in that students should learn to use these tools as they will have access to them in the real world. That said, I also believe students should have to learn to perform calculus the long way as well because its [sic] very important to understand how to solve a problem and why the formulas work.

Sometimes a student knows the process but makes a mistake from a class they took years ago.

From my experience CAS calculators are used daily in an MEs workplace. And the education should be preparing students for today's workforce. With that being said the implementation of CAS should be introduced after students have mastered the fundamentals.

Q3: Cost

Most students would have a difficult time purchasing.

I agree that the cost is trivial, but does it really help the students understanding as opposed to improving test scores.

My TI-Nspire CX been really good to me on my job.

If required, be sure to have a professor that is very knowledgeable as to the functions of the CAS calculator so that students do not waste their money.

Individuals in engineering technology need to understand that certain beneficial equipment can and is effective later on. They need to think of it as an investment rather than a cost.

These calculators are more in-tune to the tech and workplaces of today and should be allowed in all classes.

My job working in engineering is much easier using these calculators. If I would not have purchased them in school, I would have purchased them at work.

Should have option go check out calculator specifically for those classes or many students are vets. Write the syllabus where it is covered with textbooks.

Many of the students are on some kind of tuition assistance program that may or may not cover the cost of the calculator. That said, it is likely the tuition programs will cover the cost if the calculators are part of the required learning materials and is included on the syllabus.

The cost isn't all that much considering the price I paid for some materials.

Regarding the use of calculators in the workplace, people writing comments agreed that calculators are always allowed and that one should be using the latest technology. Several commenters noted that work must be written down and documented, even if you are using a calculator.

Question 4 asked the alumni how much they used calculus in the workplace.

Q4 : At APSU, you were expected to take calculus and to use calculus in classes. Now that you've graduated and are in the workplace, how much do you use calculus?				
Always	Usually	Sometimes	Rarely	Never
0	1 5%	8 36%	7 32%	6 27%

Overall, the alumni responded positively to the proposal. Their concerns matched the concerns expressed by the IAB members, and the changes made following discussion with the IAB should alleviate for the most part concerns expressed by the alumni.

Students: from the students, we received 20 responses. These came from all concentration areas.

Summary of Alumni Survey Results	Agree	Neither	Disagree
Q1: Respondent Understands Role as Constituent in Continuous Improvement Process	19 95%	1 5%	0
Q2: When using mathematical tools - algebra, trigonometry, and calculus - you work with symbols, following rules to rearrange or process symbols, and you work through the numbers. After you spend some time working with the symbols by hand in math courses, should we have you use Computer Algebra System (CAS) calculators to do the symbolic work as well as crunching the numbers?	17 85%	0	3 15%
Q3: We are considering having you buy a CAS (Computer Algebra System) calculator in the $130-$160	13 65%	4 20%	3 15%

range that would help you do better in engineering technology courses. This could not be used in MATH 1530 Statistics (a required course) or other math department courses; you would have to have a different calculator for use there. We know it is a burden for some of you, but we think you can afford this and it will be worth it to you when using math in our courses.			

Question 4 (students) asked how many had taken calculus. Of the group responding, 18 (90%) said YES, and two said NO.

Students were asked in questions 5 and 6 about their experiences using calculus in their engineering technology courses.

Q5 : How Often Do You Use Calculus in your Engineering Technology Courses (EXCEPT the applied calculus course)?					
Have Not Taken Calculus	Regularly	Some	Occasionally	Rarely	Never
1 5%	5 25%	4 20%	8 40%	2 10%	0

Q6: When you need to use calculus to solve a problem in an engineering technology course, you find this ...						
Have Not Taken Calculus	Very Easy	Easy	Neither	Difficult	Very Difficult	Have NOT Used Calculus
0	0	3 15%	5 25%	8 40%	3 15%	1 5%

For both of these questions, it should be noted that these responses came from current students. Some may have not yet taken required courses where the use of calculus is required.

As with the IAB and the alumni, the student responses indicated majority support for this proposal. In addition to concerns voiced by the other groups, not surprisingly, the students showed greater concern over the costs. Again, the changes made following discussion with the IAB should alleviate concerns expressed by students.

Results of Review Process … Decision to Move Ahead with Adoption

Through this process, an initial proposal was made, reviewed by major constituent groups (faculty, IAB, alumni, and students), and modified based on responses from constituents. With these modifications, the department moved forward with the proposal.

Students would still be given instruction on traditional methods for calculus problems. With that foundation, students would be allowed – and expected – to use CAS calculators. These calculators would be listed as required items for courses, and students would be given instruction on how to use the calculators. Faculty would allow their use in classes.

Implementation

With approval of the modified proposal, the department began steps to bring CAS calculators into the curriculum. For courses beyond the introductory level where calculators would be needed, faculty were to add the TI-nspire CX II CAS calculator as a requirement in the course syllabus.

The cost of the calculators was and is a concern, and purchasing the calculator would be a burden for some students. Making the financial issue worse, some students would have purchased less-capable calculators for use in math courses. For a transition period, students would not be held rigidly to this requirement. No time period was set, but it seemed reasonable to allow some time for students to purchase the calculator.

With the requirement in course syllabi, all faculty would allow the use of these calculators in classes. In some cases, faculty needed to learn to use the calculators themselves. This was left up to the individual faculty with offers of assistance from those who had learned to use these new tools.

In courses taught by the author, these calculators are listed as required items in the syllabus. Students are given instruction on the calculators in the problem-solving course required for all majors. More limited instruction is given in other courses, such as dynamics. Traditional methods are also demonstrated.

While the primary place for teaching traditional methods is the first course in calculus, later on it seems to work well to demonstrate some problems with traditional methods first, and then to repeat the problem using the CAS calculators. This does more to address the concerns raised by constituents regarding development of skills in mathematics.

One drawback of the calculators is that they can give some algebraically peculiar results. It should help students to see the clean, analytical result, to compare that with the CAS calculator result, and to have the instructor show them how to rework the calculator result. This approach demonstrates some limitations and pitfalls of the CAS calculator. If one is solving a problem with trigonometric functions, one gets some odd-looking constants if the calculator is set for degrees instead of radians. It should help students recognize if something has gone wrong if they have seen this demonstrated in class.

Results

While a formal survey has yet to be taken, the change appears to be popular with students. Most have the calculators and have learned how to use them. Of primary importance, their performance in the use of calculus has improved dramatically.

Some students have had to purchase the calculators when taking a course taught by the author. For these upper level courses, it comes as a surprise that they have not already made this purchase. Likewise, some need instruction on the use of the calculators. Others do not, and some are visibly bored when this is gone over in class.

When students do have the calculators and know how to use them, they are able to do the work we require of them.

A comparison of assessment and evaluation results for two sections of the problem-solving course, one taught before and one after the implementation process, shows a dramatic improvement in results. Results are shown for the entire class and include students from all active concentrations. Due to feedback from our recent reaccreditation visit, we have changed the way we assess and evaluate performance indicators. Under our new standard, results meet the benchmark if 75% of students score at or above 75% on the work being assessed and evaluated. For ETAC of ABET, we do look at each concentration separately. The course is required for all engineering technology majors, and the results presented here are for all students in the course. This gives a larger sample and an indication on a requirement for all majors.

Comparison of Results Problem-Solving Class Sections Without (Fall, 2019) and With CAS Calculators (Fall, 2023) Performance Indicator: Calculus Problem Set on In-Class Final Exam		
	Fall, 2019	Fall, 2023
	CAS Calculators NOT Used	CAS Calculators Used
Students Taking Final Exam	28	26
Students Meeting Benchmark of 75% or Better on Calculus Problem Set	9 32%	22 85%
Highest Five Scores	100%; 95%; 95%; 85%; 80%	All 100%; 6th also 100%
Meets Criteria	NO	YES
Students NOT Meeting Benchmark	19	4
Lowest Five Scores	38%; 33%; 30%; 28%;15%	77%; 73%; 73%; 72%; 67%

Using traditional methods, the class group fell well short of the benchmark. With the CAS calculators, the class performed well beyond the minimum level to meet the benchmark. Performance of students who fell below the benchmark showed a remarkable change for the better. For the students who did not meet the benchmark, with CAS calculators the scores were close to the arbitrary benchmark level. Even these students demonstrated the ability to solve calculus problems. Without the calculators, the lowest scores were far below an acceptable level. Based on results to date, this action, driven by data from our CIP, reviewed and modified with input from our constituents, has been a success.

Future Work

This paper documents steps taken following the department's CIP to implement a change intended to improve student learning. After consultation with constituents and with their approval, the department began to require students to have and to allow them to use the new CAS calculator technology. To date, performance indicators used have been performance on set-piece calculus problems, where performance has dramatically improved. With the calculators, students perform calculus operations better – when given a calculus problem, they can solve it.

To date, we have not tested the student's understanding of why calculus is important or of the meaning of a derivative or of a definite integral. The performance indicators do not give results related to whether a student can recognize when tools from calculus should be used. The question of how well the students understand the need for calculus or when to apply these tools would be a subject for future study.

Conclusions

The department's continuous improvement process (CIP) delivered results. Assessment and evaluation of performance indicators showing the ability of students to use calculus were well below department standards. This had been a long-term problem, and earlier efforts to address the problem had failed to raise performance to an acceptable level.

A new technology, the CAS calculator, held promise as a means to improve performance. To address the need identified by the assessment and evaluation process, the author proposed that the department adopt this technology and allow the use of CAS calculators in place of traditional methods for solving calculus problems. Input on the proposal was sought from constituent groups – faculty, industrial employers through the department's Industrial Advisory Board, alumni, and students. Based on this input from constituents the original proposal for action was modified. With these modifications, the department took the proposed action. Comparison of assessment and evaluation results shows a great improvement in student performance in the use of tools from calculus. Results now exceed the department's target. Results to date show that this initiative was a success. Further, the CIP was demonstrated, providing documented evidence that the department has a functioning continuous improvement process. This documentation supports efforts for reaccreditation by ETAC of ABET.

References

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