Impact of the K to 12 curriculum on the mathematics proficiency of first year engineering students in the University of Santo Tomas Faculty of Engineering: A Preliminary Study

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Highlights

- Second year engineering students under the old engineering curricula performed better in calculus than the first cohort of K to 12 graduates enrolled as first year students in the UST Faculty of Engineering.
- Graduates of the K to 12 curriculum are insufficiently equipped with the basic competencies and skills needed to handle first-year level engineering mathematics under the new curriculum.

Abstract

This paper explores the level of preparedness of the first two cohorts of engineering freshmen, who graduated generally from the STEM curriculum, to hurdle first-year level engineering mathematics in the University of Santo Tomas (UST) Faculty of Engineering. The methodologies used by the researchers are limited to the comparison of the performance of engineering students in calculus for the past four academic years, the analysis of the mathematics preparation prescribed by the STEM curriculum, and a diagnostic exam administered to the second cohort of freshmen to assess their proficiency in basic mathematics courses. The passing percentage of the first cohort of freshmen in calculus shows that the level of mathematics preparation that STEM students received lacks in comparison with the freshmen's preparation in algebra, geometry, and trigonometry under the old engineering curriculum. This finding is confirmed by the results of the diagnostic exam administered to the second cohort of incoming freshmen, in which less than half obtained a passing mark in algebra, geometry, and trigonometry. Those who received a below satisfactory mark in the exam were required to take an online course on the math subjects that they failed. After undergoing a six-week, self-paced online math course, the students were again assessed using the same diagnostic exam to measure improvement and to determine who needed to undergo supplemental instruction. Only a slight improvement in the performance was observed. Although half of them received a passing mark in algebra, more than half still failed geometry and trigonometry. These results show that a clear gap exists between the level of proficiency expected of freshmen engineering students and the amount of mathematics preparation that they received under the SHS STEM curriculum. This study does not include student attitude and SHS STEM faculty preparedness to teach math courses in preparation to engineering.

Key Words: K to 12 basic education transition; engineering mathematics; STEM

1. Introduction

During the academic year 2016-2017, the first cohort of Junior High School students finally transitioned to the Senior High School level, in which students choose to pursue either an Academic Track or a Technical-Vocational Track. Through the addition of two more years of secondary education, graduates of the K to 12 curriculum are expected to gain enough mastery of concepts and skills needed to succeed in tertiary education. Under the Academic Track, students, who aim to enroll in engineering programs in the tertiary level, are expected to choose the Science, Technology, Engineering, and Mathematics (STEM) strand during Grades 11 and 12. Based on the SHS curriculum and program requirements, STEM students take math subjects during their Grade 11 only. These subjects include General Mathematics (i.e, Algebra, Geometry, and Trigonometry) and Pre-Calculus during the first semester; while, Statistics and Probability and Basic Calculus are taken during the second semester. Each subject is allocated 80 hours per semester. On the other hand, during their Grade 12, STEM students no longer take math subjects. Instead, the curriculum prescribes teaching science subjects such as Biology, Chemistry, and Physics (Department of Education, n.d.).

STEM	Grade 11		Grade 12	
	1st Semester	2nd Semester	1st Semester	2nd Semester
CORE SUBJECTS	Oral Communication in Context	Reading and Writing Skills	21st Century Literature from the Philippines and the World	Physical Education and Health
	Komunikasyon at Pananaliksik sa Wika at Kulturang Pilipino	Pagbasa at Pagsusuri ng Iba't-Ibang Teksto Tungo sa Pananaliksik	Contemporary Philippine Arts from the Regions	
	General Mathematics	Statistics and Probability	Media and Information Literacy	
	Earth Science	Disaster Readiness and Risk Reduction	Understanding Culture, Society and Politics	
	Introduction to the Philosophy of the Human Person / Pambungad sa Pilosopiya ng Tao	Personal Development / Pansariling Kaunlaran	Physical Education and Health	
	Physical Education and Health	Physical Education and Health		
CONTEXTUALIZED SUBJECTS	Empowerment Technologies (E-Tech): ICT for Professional Tracks	Research in Daily Life 1	English for Academic and Professional Purposes	Research in Daily Life 2
				Entrepreneurship
			Pagsulat sa Filipino sa Piling Larangan (Akademik)	Research Project
SPECIALIZATION SUBJECTS	Pre-Calculus	Basic Calculus	General Physics 1	General Physics 2
		General Chemistry 1	General Biology 1	General Biology 2
				General Chemistry 2
				Research/Capstone Project
HOURS PER DAY	5.8	6.6	6.6	5.8

Figure 1. Suggested academic track – Science, Technology, Engineering and Mathematics (STEM) strand scheduling of subjects. (Department of Education, n.d.)

As a consequence, the five-year curriculum of the various engineering programs in the country was trimmed down to four years, under the assumption that the basic competencies in math and sciences needed in engineering have already been honed in the SHS. Math subjects that were previously taken by engineering students during their first year under the old curricula, such as College Algebra, Advanced Algebra, Plane and Spherical Trigonometry, Analytic Geometry, and Solid Mensuration, were removed from the new engineering curricula. In place of these, first year engineering students take Calculus 1, which covers mostly Differential Calculus, during their first semester; while, Calculus 2, which covers mostly Integral Calculus, is taken during their second semester. In addition, Mathematics in the Modern World (MMW) is taken in the first semester. However, MMW is a general education course, not a basic engineering math course (CHED CMO No. 20 s.2013), and it is not designed as a substitute for the previous first year math courses that were taken out in the new engineering curricula. In addition, engineering students, under the old engineering curricula, took Differential Calculus and Integral Calculus during their second year, after successfully passing their algebra, geometry, and trigonometry subjects in their first year.

The intentions of the implementation of the K to 12 curriculum are good. However, the passing percentage of the first year students in Calculus 1, who graduated under the K to 12 curriculum, became an eye-opener for the UST Faculty of Engineering regarding the gap in the preparedness of SHS graduates to hurdle the demands of engineering mathematics and the expected level of math proficiency that they should have attained prior to entering the engineering program. This paper presents the results of the various intervention programs and gap analysis that UST implemented starting from the commencement of the Academic Year 2018-2019 until the beginning of the Academic Year 2019-2020 to ensure the academic success of the first two cohorts of first year engineering students who graduated from the K to 12 curriculum as well as the succeeding cohorts.

2. Methods

2.1 Comparison of passing percentage of engineering students under the new and old engineering curricula

At the end of AY 2018-2019, the number of first-year students who passed the Calculus 1 and 2 courses was compared to the passing percentage of second year students who took the Differential Calculus and Integral Calculus courses under the old engineering curricula. This was used to identify the intervention programs that UST may implement to ensure that the level of math proficiency that SHS graduates have is at par with the math proficiency of the second-year engineering students under the old engineering curricula, at the very least.

It must be noted that part of this cohort of freshmen students are non-STEM graduates who underwent a summer bridging program conducted by the UST Faculty of Engineering prior to the start of AY 2018-2019. Under CHED CMO No. 105 s.2017, all SHS graduates are eligible to enter the tertiary level regardless of the track or strand that they have taken in the SHS. This means that engineering schools in the country cannot discrimate against enrollees who did not graduate from the STEM strand. To address the perceived lack of math and science preparation that non-STEM graduates attained, the UST Faculty of Engineering offered a bridging course for enrollees coming from non-STEM strands. Eighty (80) students enrolled in the six-week bridging program, in which students were taught algebra, geometry, and trigonometry. The performance of these students were then monitored throughout the first semester of AY 2018-2019 to determine the effectiveness of this program in filling expected gaps, based on the SHS curriculum, in the math competency of non-STEM students.

2.2 Analysis of the deficit in the mathematics preparation of SHS graduates

The amount of hours allocated for mathematics subjects in the SHS was compared with the number of hours prescribed by the old engineering curricula for math subjects that are prerequisite to Differential Calculus. This is to determine which curriculum offered better preparation for engineering calculus.

2.3 Engineering Program (EngPro) Test

Based on the experience that the UST Faculty of Engineering had with the first cohort of SHS graduates, the Faculty required all successful UST Entrance Test passers enrolling in the various engineering programs for the Academic Year 2019-2020 to undergo a diagnostic exam. The Engineering Program (EngPro) test was designed to assess the aptitude level of the incoming freshmen students on algebra, geometry, and trigonometry. Table 1 shows the topics per subject covered in the diagnostic test.

Table 1. Topics per subject covered in the Engineering Program (EngPro) diagnostic test

Algebra		**Geometry**		**Trigonometry**	
Topic 1	Operations on Algebraic Expressions	**Topic 1**	Polygons	Topic 1	Six Trigonometric Functions
Topic 2	Special Products	**Topic 2**	Circles	Topic 2	SpecialAngles
Topic 3	Factoring	**Topic 3**	Rectangular Parallelepiped	Topic 3	Reciprocal, Quotient, and Pythagorean Identities
Topic 4	Remainder and Factor Theorems	**Topic 4**	Cylinders, Cones, and Spheres	Topic 4	Negative-Angle and Sum and Difference of Angles

					Identities
Topic 5	Linear Functions	**Topic 5**	Analytical Geometry (Lines)	Topic 5	Double Angle and Half-Angle Identities
Topic 6	Quadratic Functions	**Topic 6**	Analytical Geometry (Circles and Parabola)	Topic 6	Law of Sine and Cosine

This two-hour onsite paper-based examination is composed of 60 multiple choice type questions: 20 algebra questions, 20 geometry questions, and 20 trigonometry questions. The passing percentage for each subject was set at 50%. Those who attained below satisfactory marks were then required to take an online Basic and General Engineering Mathematics (BGEMs) course deployed online via UST Cloud Campus using Blackboard, which is the learning management system (LMS) of UST.

2.4 Basic and General Engineering Mathematics (BGEMs) final test

The BGEMs online course was a six-week self paced course in which incoming freshmen students learned algebra, geometry, and trigonometry through modules uploaded on Blackboard. Eight (8) faculty members teaching Mathematics in the Faculty of Engineering were responsible for developing the online modules. The team was composed of six faculty members, who had more than 10 years of teaching experience; while, the remaining two had close to five years teaching experience. All of the team members received a “Satisfactory” to “Very Satisfactory” overall competency evaluation rating for the past five academic years and have postgraduate degrees in either engineering or mathematics. The head of the team that oversaw the module development has a PhD in Mathematics. On the other hand, the member of the team who designed the course site has been one of the top users of Blackboard in the UST Faculty of Engineering for the past three academic years.

This course culminated with a paper-based final test, administered onsite, to assess the improvement in the aptitude of the students in the subjects that they failed in the EngPro diagnostic exam. All the questions in the BGEMs final test and in the EngPro exam are similar.

3. Results and discussion

3.1 Passing percentage of engineering students in Calculus 1 (Differential Calculus) and Calculus 2 (Integral Calculus)

Figure 2 shows the passing percentage of the last four cohorts of engineering students who took the Calculus 1 (Differential Calculus) course. Under the last three years of the implementation of the old engineering curricula (AY 2014-2015 up to AY 2016-2017), there is around an 80-90% passing percentage in the number of students who took the Differential Calculus course. However, the passing percentage of the first cohort of first year engineering students who graduated under the K to12 curriculum dropped to 61% at the end of the first semester of AY 2018-2019.

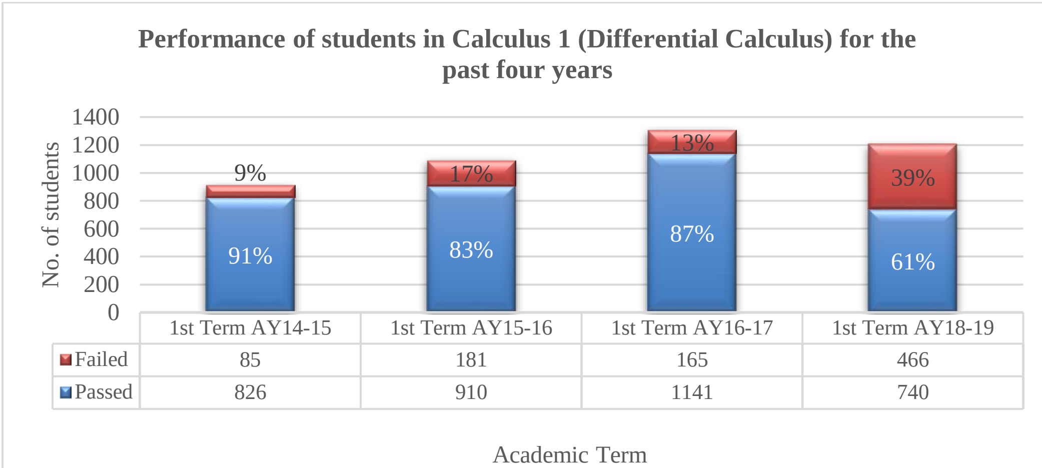


Figure 2. Performance of students in Calculus 1 (Differential Calculus) from AY 2014-2015 until AY 2018-2019.

The performance of the non-STEM students who underwent the summer bridging program was also poor. Only 26 out of the 80 students (32%) passed the Calculus 1. Figure 3 shows that this segment represents 2% of the entire cohort.

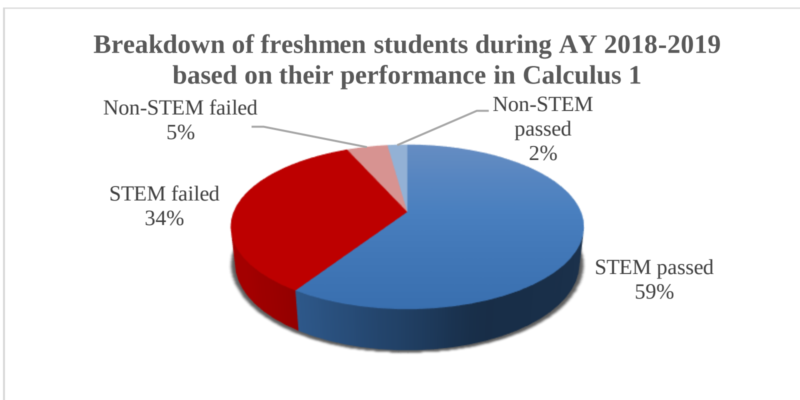


Figure 3. Percentage of STEM and non-STEM graduates in the 2018 cohort who passed and failed the Calculus 1 course

On the other hand, Figure 4 shows the comparison of the performance of the second year students in Integral Calculus under the old engineering curricula from AY 2015-2015 to AY 2016-2017 versus the performance of the first year students, who graduated from the K to 12 curriculum, in Calculus 2 at the end of AY 2018-2019. Although it can be seen that students who graduated from the K to 12 curriculum performed quite similarly to the second year students under the old engineering curricula, the consistently low passing percentage of the 2018 cohort in engineering mathematics reveals the need for the immediate implementation of intervention programs for the next cohorts of incoming engineering students to augment their chances of passing these two major first year level engineering mathematics subjects.

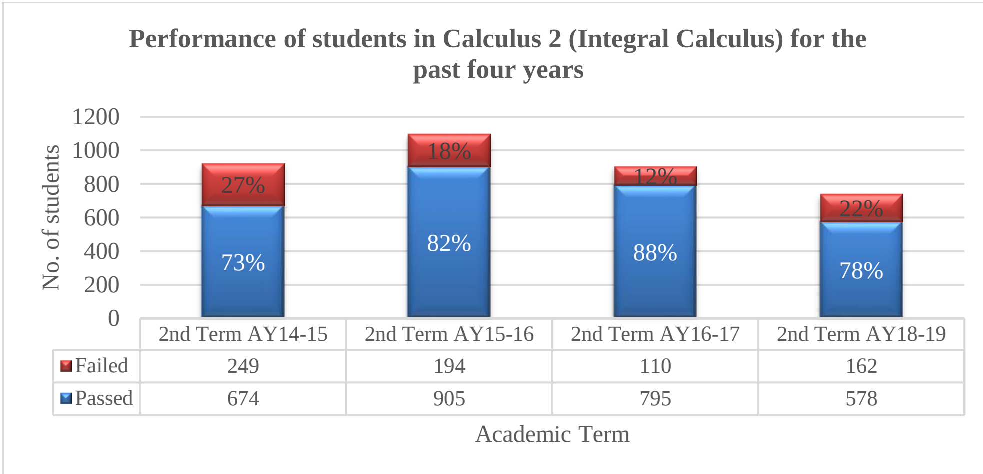


Figure 4. Performance of students in Calculus 2 (Integral Calculus) from AY 2014-2015 until AY 2018-2019.

3.2 Comparison of the math preparation in the SHS curriculum and in the old Engineering curricula

The amount of engineering math preparation that SHS graduates obtained is compared with the number of hours allocated by the old Engineering curricula for the math subjects that were considered prerequisite to Differential Calculus. Table 2 shows that the senior high school curriculum has more lecture hours for pre-engineering mathematics compared to the lecture hours of the math courses that are prerequisites of Differential Calculus under the old Engineering curricula. However, on closer inspection, the Statistics and Probability subject taken during Grade 11 cannot be considered a prerequisite of calculus per se. This therefore cuts down the number of hours dedicated for preparation to engineering calculus to 240 hours. In addition, although pre-calculus and basic calculus are already introduced to SHS students, the amount of hours dedicated for basic math courses, such as algebra, geometry, and trigonometry, is significantly lower compared to the number of hours that the old engineering curricula requires for the teaching of these foundational math courses. Lastly, the fact that math courses are taught only during Grade 11 may have significantly prevented continuity among SHS graduates in honing their aptitude in algebra, geometry, and trigonometry since a one-year gap exists (Grade 12) before they can fully apply their math skills in Calculus 1 during their first year in college.

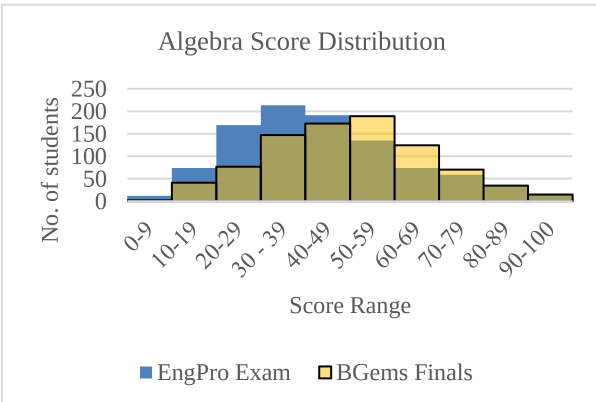
Table 2. Comparison of lecture hours per subject per semester under the new K to 12 curriculum and under the old Engineering curricula

SHS Grade 11 Math		**Prerequisite Math Courses for Differential Calculus under the old Engineering curricula**		
Subject	**Credit hours/ semester**	**Course**	**No. of lecture units**	**Credit hours/ semester***
General Mathematics	80	College Algebra	5	90
Pre-Calculus	80	Solid Mensuration	2	36
Statistics and Probability	80	Analytic Geometry	2	36
Basic Calculus	80	Plane and Spherical Trigonometry	3	54
Total	320		Total	216

*Based on an 18-week semester schedule

3.3. EngPro diagnostic exam and BGEMs final exam results

Majority of the incoming freshmen students, who took the EngPro diagnostic exam prior to the start of AY 2019-2020, received a failing mark (<50% score) in all of the basic math subjects. Only 32% of the 2019 cohort passed algebra, 36% passed geometry, and 13% passed trigonometry. After undergoing the BGEMs online course, students who got a failing mark in at least one of the subjects in the diagnostic exam were required to take the test once again. Figures 5, 6, and 7 show that the score distribution of students in algebra, geometry, and trigonometry in the EngPro diagnostic exam levelled off slightly towards the higher score ranges in the BGEMs final exam, signifying a slight improvement in the performance of the students. Half of the students passed algebra, 45% passed geometry, and only 32% passed trigonometry.



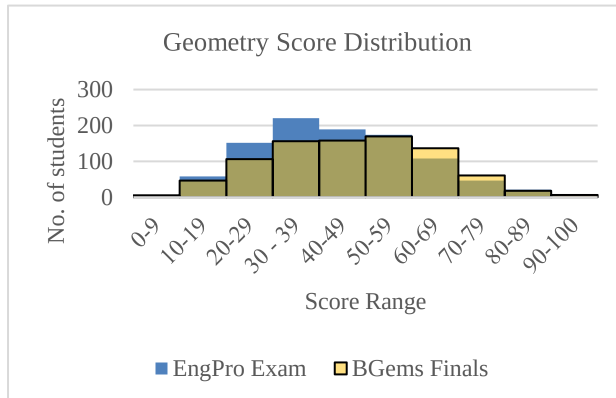


Figure 5. Score distribution in algebra for EngPro diagnostic exam and BGEMS final exam

Figure 6. Score distribution in geometry for EngPro diagnostic exam and BGEMS final exam

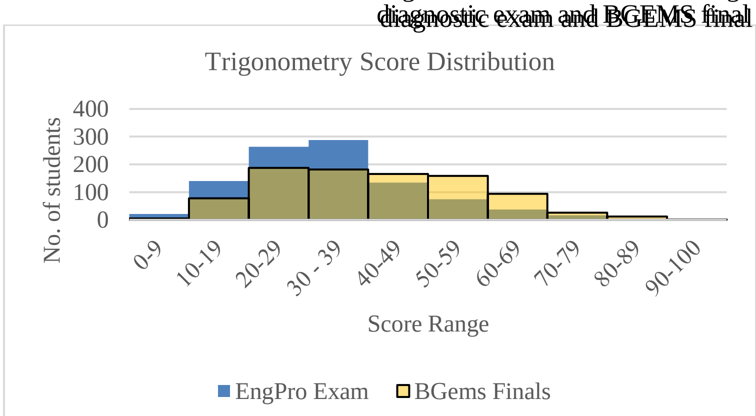


Figure 7. Score distribution in trigonometry for EngPro diagnostic exam and BGEMS final exam

4. Conclusions

The low passing percentage in Calculus 1 of the first cohort of SHS graduates enrolled in the UST Faculty of Engineering and the poor performance of the second cohort of SHS graduates in the diagnostic exam for algebra, geometry, and trigonometry show that there is a clear gap in the expected math proficiency of the SHS graduates enrolling in engineering programs and the actual level of math aptitude, which they generally have upon graduation from SHS. These results show the urgent need for the immediate review of the SHS curriculum, especially in the STEM strand, to assess whether this provides future engineering students with the optimum level of preparation to successfully hurdle engineering mathematics. In view thereof, providing students more time to master basic mathematics, such as algebra, geometry, and trigonometry, may augment their chances to succeed in learning engineering calculus better, thereby, equipping them with the necessary foundation for engineering design and in solving complex engineering problems. On the other hand, engineering schools in the country may need to implement intervention programs that increase opportunities for success of students in attaining outcomes where proficiency in mathematics is key, and in monitoring the effectiveness of these interventions in achieving such outcomes. Ultimately, the results of this preliminary study underpin the need for a larger study to be conducted, which addresses the same set of objectives but involving other engineering schools in the country. This is to better assess the extent of the problem in the mathematics proficiency of STEM graduates intending to enroll in various engineering programs. Lastly, this study opens the conversation on the re-evaluation of the current pedagogical content knowledge of engineering mathematics teachers, to assess whether this adequately serves the purpose of educating a new breed of engineering students who have been accustomed to a different style of teaching in the senior high school. This is crucially needed now when the new engineering curricula requires much higher level mathematics compared to its predecessor, as a response to the changing needs of the industry and the drive to make engineering graduates more globally competitive.

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