Comparison of International Students' Competency Levels in the Fundamentals of Engineering Technology Courses

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Abstract

In this paper, challenges to meet the competency levels needed for fundamentals of engineering technology classes are identified. Groups of students were examined for the preparedness in mathematics and sciences, as well as in basic fundamentals of engineering technology subjects in selected classes at different semesters. A test instrument was developed to measure the student population's knowledge levels in these classes and strategies are being proposed to assist the students in attaining the minimum competency levels.
This study seeks answers to the question on whether international students have the same or better knowledge of basic mathematics, sciences and fundamentals of engineering technology compared to their domestic counterparts. The hypothesis was that "the barriers in their communication and language skills, rather than their basic knowledge of sciences, mathematics, and fundamental of engineering technology subjects are the main factor that prevents international students to demonstrate their class competencies."

Introduction

At the present time, one of the many consequences of globalization is the internationalization of higher education. Governments are investing in international education and students' mobility [1] leading to the increase of the international students' population in U.S. universities. Among many challenges faced by those students (related to their different cultures, languages and social habits), the most demanding are the settlement in the new environment, the adaptation of their information processes and communication skills [2]. Often non-native English speakers may not feel fit or capable to interact with their domestic counterparts in class activities.

However, the implications of the internationalization of the campuses populations goes far beyond the issues of adaptation and socialization; issues related to pedagogy and academic performance and how to address them, remains to be answered by educators. Among these issues, one of the most recurrent is the perception shared by many instructors on the differences in the basic engineering competencies between domestic and international students, which is the focus of this study. Previous studies have shown that talking and working in groups with their domestic counterparts is recognized to be the most important factor in perceptions of communication competency [3].

Competencies in Fundamentals of Engineering (FE)

Accreditation of engineering degrees assures that the contents of the degree meets national and international standards of the profession for which the degree prepares its graduates [4], and academic programs aiming to train students to perform in engineering fields are required to include in their curriculums the development of competencies in its fundamentals [5].
States professional licensing engineering boards' grants the Professional Engineer (PE) license when certain experience and education requirements are met, and the Fundamentals of Engineering

(FE) exam is part of the evaluation. The National Council of Examiners and Surveying (NCEES) specify the FE exams to cover basic aspects of different engineering curricula, such as mathematics, statistics, statics, dynamics, electricity, materials, etc. [6], [7].
In the assessment of the competencies in fundamentals of engineering, the NCEES' FE exam results can be used as one measurement of the following student outcomes included in ABET General Criterion 3 for Engineering Technology Programs [8]:

(a) An ability to apply knowledge of mathematics, science, and engineering;
(b) An ability to design and conduct experiments, as well as to analyze and interpret data;
(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;
(e) An ability to identify, formulate, and solve engineering problems;
(f) An understanding of professional and ethical responsibility;
(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

To compare the fundamental of engineering competencies between international students and their domestic counterparts, the same measurement was employed, i.e., Criterion 3 for Engineering Technology programs as suggested by NCEES. It was also verified if the proficiency in English (as a measure of communication and language skills) is a factor in the international students' ability to demonstrate their class competencies.

Survey

The assessment instrument used to evaluate the student population's knowledge in fundamentals of engineering technology subjects was a test applied in a survey format, administered to 142 junior and senior students from the Mechanical and Manufacturing and Electronics Engineering Technology programs, in different semesters. In general, students are not specifically prepared for the test in the same level that professional engineer (PE) candidates are. For this reason, our test consisted of 40 questions instead of 119 included in the FE exam. The 40 questions were taken from past exams and/or appropriate study guides [9], [10], [11], [12]. NCEES specifications [6], [7] for the test contents were followed.

From the 142 participants, 40 declared themselves as international students. The scores in the English proficiency test were used to measure the proficiency in the English language. The Test of English as a Foreign Language (TOEFL) is a standardized test to measure the English language ability of non-native speakers wishing to enroll in English speaking universities. This test is accepted by many English-speaking academic and professional institutions. TOEFL is one of the two major English-language tests in the world, the other being the International English Language Testing System (IELTS). All international students surveyed are non-native English speakers; for this reason, no consideration was given to countries or regions of origin, which otherwise would have an influence in the results of this study.

The international students are required to take the English proficiency test prior to admission into a college and therefore a metric is available for the evaluation. A criterion was necessary to equate the students who did not take the English proficiency test (that refers to all domestic students in

the group). The adopted criterion was how the IELTS scores the language proficiency level of people who want to study or work where English is used as a language of communication. It uses a nine-band scale below to identify levels of proficiency [13], as shown in Table 1.
:

Band Score	Skill Level	Description
9	Expert user	The test taker has fully operational command of the language. Their use of English is appropriate, accurate and fluent, and shows complete understanding.
8	Veru good user	The test taker has fully operational commando of the language with only occasional unsystematic inaccuracies and inappropriate usage. They may misunderstand some things in unfamiliar situations. The handle complex and detailed argumentation well.
7	Good user	The test taker has operational commando of the language, though with occasional inaccuracies, inappropriate usage and misunderstandings in some situations. They generally handle complex language well and understand detailed reasoning.
6	Competent user	The test taker has an effective command of the language despite some inaccuracies, inappropriate usage and misunderstandings. They can use and understand fairly complex language, particularly in familiar situations
5	Modest user	The test taker has partial command of the language and copes with overall meaning in most situations, although they are likely to make many mistakes. They should be able to handle basic communication in their own field.
4	Limited user	The test taker's basic competence is limited to familiar situations. They frequently show problems in understanding and expression. They are not able to use complex language.
3	Extremely limited user	The test taker conveys and understands only general meaning in very familiar situations. There are frequent breakdowns in communication.
2	Intermittent user	The test taker has great difficulty understanding spoken and written English.
1	Non-user	The test taker has no ability to use the language except a few isolated words.
0	Did not attempt the test	The test taker did not answer the questions.

Table 1 Band Score per Proficiency Level IELTS test (Source: https://www.ielts.org/en-us/about-the-test/how-ielts-is-scored)

According to IELTS the mean overall and individual band scores achieved by 2015 (General Training) test takers from the United States is 7.7 [13]. It was assumed that our domestic students would score the same average IELTS score if they would take the test.

That was also necessary to equate the scores of students who took the TOEFL test with those who took the IELTS test (TOEFL and IELTS have different score scales). Educational Testing Services (ETS) developed a comparison between TOEFL and IELTS scores [14], as shown in Table 2:

:

TOEFL Score	IELTS Band
0 - 31	0 - 4
32 - 34	4.5
35 - 45	5
46 - 59	5.5
60 - 78	6
79 - 93	6.5
94 - 101	7
102 - 109	7.5
110 - 114	8
115 - 117	8.5
118 120	9

Table 2 Comparison between TOEFL and ILTS Scores, with the highest degree of confidence (Source: https://www.ets.org/toefl/institutions/scores/compare/)

Survey results

The analysis of the data collected from the survey shows that there is a negligible correlation (R^2) between the IELTS and the FE test scores, even if mathematics and other subjects are analyzed separately. The average scores for both groups (domestic and international students) are similar, even considering the average IELTS is lower than 7.7 for the international students, as shown in the Table 3 below:

	Average IELTS Score	Average Math Score (%)	Average FE Score (%)	Overall Average Score (%)
International Students	5.7	35.67	55.17	49.94
Domestic Students	7.7	43.05	58.30	54.21

Table 3 Summary of Test Scores

The most significant discrepancy was in the mathematics portion of the test, with a difference of 7.38% in favor of the domestic students; that may be explained by the fact that approximately 70%

of the international students transferred mathematics credits from other institutions, while most domestic students (approximately 90%) did not.
The initial hypothesis that "the barriers in their communication and language skills, rather than their basic knowledge of sciences, mathematics, and fundamental of engineering technology subjects are the main factor that prevents international students to demonstrate their class competencies" could not be confirmed by the data. There is no indication that language and communication skills and the acquisition of knowledge in fundamentals of engineering are related.

NCEES does not publish a passing score for the FE exam, although opinions and estimates abound in this subject. However, it can be argued that in general, institutions of higher education offering engineering and technology programs have lowered their threshold from C (70% or above) to D (60% or above) to pass a class, along with grade inflationary pressures [15].
It is important to notice that on average the perception of poor performance by international students is not reflected in course grades between the two groups, meaning that eventual instructor's bias is not resulting in lower grades when performance is similar. That can be seen in the grade distributions collected randomly among different upper level classes in different semesters (Table 4)

Grade Distribution (%)		
Grade	International Students	Domestic Students
A	4.55	6.15
A-	4.55	12.31
B+	13.64	21.54
B	22.73	12.31
B-	13.64	20.00
C+	4.55	6.15
C	22.73	12.31
C-	4.55	3.08
D	4.55	3.08
F	4.55	3.08
Note: the average of grades granted to international students is approximatelly 30% of the total.		

Table 4 Grade distribution

Communication Skills

Effective communication enables students to acquire skills and develop concepts and ideas. The study conducted by Mahmud [16] clearly demonstrates the strong relationship between communication abilities and academic performance. The lack of a significant correlation between language and communication skills and the acquisition of knowledge in fundamentals of engineering and mathematics does not imply in any way the development of these skills is not an essential component of engineering education. Recurrent complaints from our Industry, Alumni, and Students' Advisory Board members, emphasize the industry demand for graduates with appropriate communication and writing skills.

A review of literature indicates that communication skills have been identified as a component of high importance in the employability in the manufacturing industry [17]. Jensen states that "the future will also demand a higher level of ability to communicate about technically complex matters, both to members of other professions and to lay people. Successful collaboration depends on the ability to communicate available knowledge effectively" [18].
According to Riemer [19] four sources of weakness that can have a significant impact on an engineer's communication skills education were identified as:

- Students' attitudes to communication;
- Insufficient course content;
- Deficient or inappropriate teaching methods;
- Lack of opportunity for engineering students to practice communication skills.

The development of writing skills across the curriculum is not new in engineering programs. Initiatives to provide opportunities to improve communication skills through the inclusion of written and oral communication components are well documented in the literature [20].
In our Engineering Technology programs, a technical writing course (EGT291W – Writing in Engineering Technology) is a required general education course, in the written communication category (this course can be replaced by the course ENG291 – Advanced College Writing). The catalog description for this course is "Introduction to writing for the engineering and engineering technology professions. Definitions, descriptions, presentations, reports, manuals, and proposals are covered. Reader-centered, process-driven writing and presentation skills are developed centered on the engineering professions" [21] .

Vertical Integration

A vertical integration of projects in different courses in order to improve the evaluation of the students' knowledge of the subject matter, as well as help facilitate the ABET assessment process [22] is proposed, and it is being gradually implemented [23]. The existing program capstone course EGT417 (Senior Project in Engineering Technology) is being used as the class where the students will conclude and present their senior projects as the culminating effort towards graduation. This course includes lectures in technical writing and technical reporting techniques as highlighted in Table 5.

CLASS SCHEDULE & ACTIVITIES				
Week	**Date**	**Meeting**	**Activities**	**Important Events and Assignments Due Dates**
1		Meeting	Introduction Machine Shop Safety Chapter 1 – The Nature of Technical Writing Chapter 2 – Technical Writing Basics	
2			Abstraction, Audience, Ethics in Tech. writing, Plagiarism	
3			Project proposal / LOI Due	Project topic and Gantt chart due date
4		Meeting	Chapter 3 – The Writing Process Chapter 4 – Scientific Writing	
5			Chapter 5 – Business Communications	
6			Chapter 7 – Using Graphical Elements	Progress Report 1
7		Meeting	Chapter 6 – Technical Reporting	
9			Chapter 9 – Writing for E-Media	Progress Report 2
10		Meeting	Chapter 10 – Writing with Collaborators	
12			Methodology – finalized	
13		Meeting	Calculations, Cost Analysis, Evaluation Due	Progress Report 3
15			Results, Discussion of Results, Graphs Due Plus the final draft of the paper	**Project report final draft due to EGT faculty**
16		Meeting for presentations	**Project presentations are scheduled (tentative)**	**Students are required to make a D-page-size poster of their presentation**

Table 5 Senior Project Class (EGT417) syllabus activities

Combined with the EGT291W class, vertical integration offers additional opportunities for the students to improve their writing and communication skills. Attention was also given in the attainment of the students' outcome "g" (SO7) which is mapped according to the ABET accreditation criteria [22] as depicted in Table 6, below:

Map of Course Competencies with Student Outcomes
(1 - Direct & Strong Link, 2 - Indirect Support)

Course \ MMET Outcomes	SO1	SO2	SO3	SO4	SO5	SO6	SO7	SO8	SO9	SO10	SO11
EGT417 - Senior Research & Design in Eng. Technology	1			1		1	1	1	2		1

ABET CRITERION 2 (PROGRAM OUTCOMES)
SO1. [a]: An ability to select and apply the knowledge, techniques, skills, and modern tools of mechanical and manufacturing engineering technology to the design, manufacturing, testing, evaluation, and maintenance of mechanical and manufacturing systems;
SO2. [b]: An ability to select and apply a knowledge of mathematics, science, engineering, and technology to selection of materials, manufacturing processes, tooling, automation, production operations, maintenance, quality, industrial organization, management and statistics to solve mechanical and manufacturing problems;
SO3. [c]: An ability to conduct standard tests and measurements of engineering materials, statics, dynamics, fluid power, and electronics;
SO4. [d]: An ability to:
I. design systems, components, or processes and apply to mechanical and manufacturing projects;
II. produce drawings and related electronic data files and apply to the areas of mechanical design, tool design and machine design;
SO5. [e]: An ability to function effectively as a member or leader on a technical team;
SO6. [f]: An ability to identify, analyze, and solve engineering technology problems in;
I. mechanical and manufacturing processes, planning, optimization and automation;
II. facilities planning, materials handling and robotics;
SO7. [g]: An ability to apply written, oral, and graphical communication in both technical and nontechnical environments; and an ability to identify and use appropriate technical literature;
SO8. [h]: An understanding of the need for and an ability to engage in self-directed continuing professional development;
SO9. [i]: An understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity;
SO10. [j]: A knowledge of the impact of engineering technology solutions in a societal and global context; and
SO11. [k]: A commitment to quality, timeliness, and continuous improvement.

Table 6 Table of Course EGT417 Competencies to Students Learning Outcomes

Conclusion

Despite the inconclusive results of the survey, a wealth of evidence can be found in the literature showing that communication skills are an essential component in engineering education. How a deficiency in this area can affect the academic performance of international students, notably in obtaining the competence levels needed for fundamentals of engineering technology type classes, could not be established in our programs' domain.

The recurrent perception shared by many instructors on the differences on basic engineering competencies between domestic and international students might be due to cultural and behavioral characteristics of international students. However, it can be argued the underlying factors fueling

that perception might be because some international students do not remove their reading and writing deficiencies until the very last semesters during their educational career at the college, despite repeated faculty and advisors' recommendations to address these deficiencies. Eventual instructors' bias is not resulting in lower grades when performance is similar, when compared with domestic students.

Class reports, project reports, and presentations are required as part of some engineering technology courses throughout the curriculum, offering additional opportunities for students to improve their communication skills.
A test instrument was developed to measure the student population's knowledge levels in fundamentals of engineering. This research will continue and the test will be administered to junior and senior students from the Engineering Technology programs, at the beginning of upcoming semesters to evaluate how beneficial the vertical integration strategy is to the international students. Conclusions to be drawn from the data may clarify if technical competency levels will be improved and if any distinction exists between the two groups (international and domestic students), confirming (or not) if communication skills are a factor in that distinction.

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