Are Dual-Degree STEM Programs Effective? An Intramajor, Comparative Study of the Success of Students in a Dual-Degree Engineering and Business Program

Craig A. Calvert
University of Connecticut

Abstract

A critical evaluation was performed comparing final course grades earned by dual-degree STEM students with their peers in the corresponding single-degree programs. The goal was to understand if students in a dual-degree STEM program can obtain grades comparable to their single program peers. There is no published analysis on how the final course grades of these dual-degree STEM students compare with those of the single-program students in their respective courses. A set of success factors was developed and showed that the dual-degree STEM students achieved comparable success on all three factors when compared to their single-degree peers. The results also showed that there was no evidence of a senior slump in their final spring semester. The results of this research can be used to further understand the relationship between dual-degree and single-degree program success along with engineering and business student success. Recruiting staff at universities can use these results to convey to hiring agents that dual-degree STEM students are capable in both component programs. University administrators, who are considering creating a dual-degree STEM program, can use these results to understand that students in dual-degree programs can be as successful as the component programs.

Keywords

STEM, Dual degree, Engineering education, Business education, Program assessment

Introduction

Objectives

Students graduating from the Management and Engineering for Manufacturing (MEM) program at the University of Connecticut, Storrs (UConn) earn a degree from both the School of Engineering and the School of Business. The MEM program is a science, technology, engineering, and math (STEM) program that was formed in 1990 and is the only program of its kind combining two STEM components (engineering and manufacturing) with a non-STEM component (business). The MEM program and curriculum are similar to other programs (discussed in the Background section below) and the analysis here, while focusing on MEM, can be generalized to these other multidisciplinary STEM programs. There are no studies that quantitatively analyze the success of these STEM students in engineering or business classes compared with students from the component business and engineering majors. One study similar to this research compared the success of engineering and business students after completing an analytics project (Scala, Tomasi, Goncher, & Bursi, 2018). That research concluded that the engineering and business students reacted differently to the same activity – with engineers showing higher scores. Based on discussions and meetings with the author, there is an assumption by engineering faculty that the MEM students do not have equivalent technical skills when compared to the students in the engineering programs. Also, through discussions and meetings with the author, on the business side, there is a perception by business faculty that MEM students will not do as well since they are perceived by these faculty as more technically (engineering) focused. A quantitative analysis of these issues was developed and used to address whether students from a dual-degree program, like MEM, can perform as well as their engineering and business school peers.

The research presented in this article builds off of past work that analyzed the success and course patterns of students entering STEM programs (Wang, Lee, & Wickersham, 2019). This previous work also implemented the use of success metrics and course map analysis to determine student success. While the previous work studied transfers into STEM fields, the work discussed here used a similar methodology (Wang et al., 2019) to study students within a STEM program. In addition, the previous work looked at the connection between course-taking patterns and transfer outcomes in STEM. The research in this paper compared the final course grade for MEM students from an engineering or business course with others that were taking the same course. A set of success factors were developed and used to provide a quantitative analysis. These numbers were used to test the five questions presented below.

1. Are MEM students better engineering and business students than their single degree peers?
   - Business < MEM > Engineering
2. Are MEM students equal to their engineering and business student peers?
   - Business = MEM = Engineering
3. Are MEM students worse than their engineering and business student peers?
   - Business > MEM < Engineering
4. Are MEM students better at one major than their engineering and business student peers?
   - MEM < Engineering; MEM > Business
   - MEM > Engineering; MEM < Business
5. Is there any measurable impact of taking the courses during the fall and spring semesters?
   - In particular, is there a "Senior Slump" causing a lower grade in the spring semester of the senior year compared to the fall semester of senior year.

No research has been conducted to study these questions for the MEM program. Therefore, this research will provide new insights into the MEM program curriculum and student success and provide analysis techniques that can be used for other multidisciplinary programs – including multidiscipline STEM programs.

Justification

It is important to set up MEM students for success, as research has found that over 25 percent of STEM students do not remain in a STEM field by age 30 (Jelks & Crain, 2020). A study of one liberal arts college graduation rates found that 38 percent of students classified as STEM at one point in their college career do not graduate with a STEM major (Walczak et al., 2020). Other research on STEM discusses the importance of instructors in the persistence outcomes of STEM students (Ferrare & Miller, 2020). MEM majors at UConn take 138 credits, which is 18 more than is typically required for a major and 12 less than a double major (UConn internal academic standards). Table 1 shows a list of courses and course titles by category that MEM students are required to complete. The courses span the entire STEM spectrum with the "S" in the core science classes, "T" as a part of the manufacturing curriculum, "E" from the engineering courses, and the "M" from the core math courses. Table 1 can be used to match the course number used throughout the paper to the course title. Given that courses at UConn are generally 3 credits for a non-lab, this means that a typical MEM major is taking six extra courses during college.

It is important to understand that these STEM students are not only achieving success after graduation

Courses: 13 **Engineering**	*Courses: 9* **Business**	*Courses: 9* **MEM**	*Courses: 9* **Science/Math**	*Courses: 7* **General Education**
CE 2110 Applied Mechanics I	**ACCT 2001** Financial Accounting	**MEM 1151** Intro to MEM	**CHEM 127** General Chemistry	CA1: Arts & Humanity
CE 3110 Mechanics pf Materials	**ACCT 2101** Managerial Accounting	**MEM 2210:** Manufacturing Equipment Lab	**ECON 1200** Principles of Economics	CA1: Arts & Humanity
CSE 1010 Intro Computers for Engineers	**BLAW 3175** Legal and Ethical Envir of Business	**MEM 2211** Intro to Manufacturing Systems	**MATH 1131** Calculus I	CA2: Social Science
ECE 2000 Electr & Comp Engineering	**ELECTIVE**	**MEM 2212** Intro to Manufacturing Lab	**MATH 1132** Calculus II	CA2: Social Science
ELECTIVE	**FNCE 3101** Financial Management	**MEM 3221** Intro to Production Processes	**MATH 2410** Differential Equations	CA4: Diversity and Multiculturalism
ENGR 1000 Orientation to Engineering	**MGMT 3101** Intro Management	**MEM 3231** Computers in Manufacturing	**MATH 2110** Multivariate Calculus	**ENGL 1007 or 1010 or 1011** Writing
ENGR 3215 Industrial Statistical QC	**MGMT 4900** Strategic Planning	**MEM 4225** Advanced Production Processes	**PHYS 1501** Physics for Engineers I	**ECON 1200** Principles of Economics
ME 2233 Thermodynamics	**MKTG 3101** Intro Marketing	**MEM 4971** Senior Design I	**PHYS 1502** Physics for Engineers II	
ME 3221 Manufacturing Automation	**OPIM 3801** Project Management	**MEM 4972** Senior Design II	**STAT 1000** Statistics	
ME 3227 Design of Machine Elements				
ME 3263 Sensors and Data				
MSE 2101 Material Science and Engineering I				
MSE 2102 Material Science and Engineering II				

Table 1. Complete list of the courses, by category, which must be completed by MEM majors

(currently the highest average salary, $65,500, of School of Business graduates), but also that the MEM program is producing graduates with the skills that the major requires. While starting salary is a strong measure of success, it does not measure the quality of the two components of the degree. If these STEM students do not have strong engineering skills or business skills, how should a curriculum be adjusted to fit this deficiency? The data analyzes all engineering and business courses that MEM students have taken over the past five years. Analysis of this data set helps to identify weak areas that can be addressed through curriculum changes. Such changes may impact the number and type of courses that need to be taken.

Qualitatively, it is important for these STEM students to know these results so that they can see themselves as both engineers and businesspeople. When spending a significant amount of time attaining such a complex degree, it is useful to know how these STEM students compare to their engineering and business peers. When searching for jobs, these STEM students will know that they can target either engineering or business positions. Faculty advisors can be confident that they are sending a graduate into a position where they can succeed. Employers can see the benefit of such a scarce skill set and see the added value of paying a higher salary to a multi-discipline STEM program graduate. Finally, those that work in multi-discipline STEM programs will have a quantitative assessment to rebut others who might look at these STEM programs as an incomplete engineering degree and an incomplete business degree. It will go a long way to truly call these STEM students and graduates by both titles that they have earned. STEM students and graduates can be engineers and businesspeople.

For more information on the MEM major. Visit the following webpage: www.mem.uconn.edu.

Background

There are many programs that are similar to the MEM program; however, many of them are engineering management programs that do not provide a core set of courses on manufacturing and/or only confer one degree from one school. MEM, by definition, provides a manufacturing component and is a dual-degree program that confers two degrees, one from engineering and the other from business. Even with these differences, the related programs provide a good comparison to UConn's MEM program, as these programs have significant engineering and business components. It is important to note, that programs defined their success through post-graduation statistics (which are generally very favorable) and not through direct comparison of the courses within the program. Another issue is that the literature or other publications may not be clear on the definitions of a dual-degree program (Knight, 2011). The generally accepted definition of a dual-degree is two separate degrees earned simultaneously and earned/conferred at the same time. The programs must be highly coordinated and ultimately reduce the time to obtain either degree separately (Ngo, 2020). A Double major is a single degree with two areas of concentration (Ngo, 2020).

The dual-degree programs can be composed of engineering and business courses that are based on skills identified by industry experts. Several previous papers (discussed below) discuss the key skills that need to be addressed for linked engineering and business programs. The assessments separate perceptions of needs based on categories such as academics, industry, and students (Nguyen, 1998)(Karimi & Pina, 2021). The perceived needs to be addressed by the linked curriculum do vary by category, but clearly identify that a broad skill set is needed. There have been initiatives in curriculum development that have implemented combined engineering and business capstone projects to increase the exposure of engineering students to business skills (Franchetti & Ariss 2016). Other research evaluated perceptions of graduates in the workforce (Josephine Flemming et al., 2010). This research concluded that employees who graduated with dual-degrees do not have a uniform perception of skill sets by employers; however, it was suggested that dual-degree graduates could be promoted more rapidly.

Several papers (discussed below) discuss the specific needs of manufacturing professionals. Several papers discuss the manufacturing curriculum needs or discuss factors manufacturing professionals use in selecting universities from which to hire manufacturing graduates (McGunagle & Zizka, 2020)(Jang, 2015) (Todd, Red, Magleby, & Coe, 2001). The two top rated responses were related to 1) having a manufacturing degree and 2) having relevant manufacturing courses. An analysis (using the House of Cards approach) assessed the business skills that were most important for manufacturing engineering graduates (Saunders, L. Ken, & Saunders, 2004). Based on this assessment the faculty can address the perceived company skills within the context of the university. When considering globalizing the manufacturing curriculum, foreign language proficiency and cultural awareness need to be incorporated (Swearengen, Barnes, Coe, Reinhardt, & Subramanian, 2002). Finally, a dual-degree master's program for systems engineering and leadership has many of the key skills and course structure found in the other programs discussed in this paper (Brown & Mendelson, 2003).

There are similar programs that combine a business and engineering curriculum. An overview of similar programs is provided below. The differences in the programs highlight the unique curriculum of the MEM program. However, since all of them are multidisciplinary, they could potentially adapt the research methods presented in this paper to assess the individual component programs.

• Clarkson University has an engineering management program with around 300 students (Milne & Zander, 2012). This program reflects the diverse background of the MEM program by requiring students to take a combination of engineering, business, and general studies but lacks the dual degree aspect of the MEM program.

•There are multiple double degree programs in Australia where engineering is combined with various business degrees (Grünwald & Zenon J. Pudlowski, 2002). These degrees are offered at over 30 schools across the country. The difference between MEM and this program is that these double degree programs require completion of two separate program qualifications, while the MEM program is one complete program.

• A comparable program to MEM is offered by the University of Singapore (National University of Singapore, 2020). This program also offers the engineering component, but it lacks the manufacturing component. The lack of the manufacturing component adds flexibility to the schedule and allows students to choose an engineering subdiscipline as a focused "module" for study.

• Lehigh University offers a program linking engineering and business with a similar course load to MEM – 137 credits (Lehigh University, 2020). Again, without the manufacturing component, this program offers the flexibility to choose an engineering subdiscipline to focus on. Enrollment is also similar to MEM with enrollment around 135 and around 45 graduates per year.

• The University of Pennsylvania offers a dual-degree in Management & Technology (M&T) combining the Wharton School of Business with Penn Engineering (University of Pennsylvania, 2020). This program is the oldest dual-degree program at the University of Pennsylvania having formed in 1977. The M&T degree is highly individualized in contrast to MEM's highly scheduled course load.

• There are master's programs that offer a combination of engineering and business. Harvard Business School offers a two-year program that is a collaboration with the MBA program and the School of Engineering & Applied Sciences (Harvard Business School, 2020). The program starts with a business focus but becomes more systems engineering focused. A more traditional Master of Science such as the one offered by Boston University, is purely for non-business students (Boston University, 2020).

• The University of Connecticut recently launched a dual MBA/MEng program (University of Connecticut, 2020). This program is 69 credits of combined MBA and MEng courses.

This is not intended to be a complete list, but it provides an overview of the different programs that offer engineering and business as a dual-degree or closely related degree type. The unique characteristics of UConn's MEM program is that it adds a manufacturing component to the engineering and business coursework, while allowing most students to graduate in four years. An analysis, such as described in this paper, on each of these programs would be of interest to assess the success of each combined programs above with their component programs.

Guidance to Reader

This paper introduces a new way to assess student success through a series of success factors. These success factors were developed to allow these factors to be adapted to other similar intra-major or inter-major analysis of course outcomes. The course grade-point-average (cGPA) is based on the GPA system used throughout the United States; however, for this study, it is used as an assessment of grades within one course. Another success factor is the key success factor (KSF), which uses the total number of A's and A-'s earned by students to identify successful completion of a course. It is most common to set an A as the only successful course outcome; however, most students would describe an A- as a success. This is generally true for harder or higher-level courses. The final factor used was an excellence factor (EF), which takes the ratio of A's to A-'s. This provides insight into how many of the successful students excelled in the course. It is expected that the EF would be lower for MEM majors in the more technical/specialized courses, since MEM majors are, by definition, generalist that might not have the depth of knowledge for a specific topic.

Parameters other than major were also studied. These parameters included course semester and student academic standing. The idea of a "senior slump" used the course semester parameter. A senior slump is when students (generally seniors) in their last semester do not work as hard in classes since they either have a job or other after-school career path that does not depend on their final semester's GPA. While some classes were low, there was no pattern of lower grades for seniors. The research also examined the breakdown by class year (freshman, sophomore, junior, senior). As might be expected, grades in these courses were slightly lower for freshmen and sophomore level students. Given that these courses are all upper-level major specific courses, it was not surprising to see this result.

Summary

The results of this research show that there is minimal difference in the overall average of success factors between MEM majors and success factors earned by the business and engineering majors. Even within individual courses there was not a significant enough difference to suggest a trend or pattern. The few exceptions are discussed below, but even these exceptions do not justify an examination of or major change in the MEM curriculum. The independence of semester and year on the course grade received suggests that the recommended class order for students is reasonable for the average student. The slight dip in the freshman and sophomore year grades, implies that allowing them to take these courses might result in a lower grade. However, the cGPA was only 0.3 lower at maximum. This is not a significant difference and could provide support for letting qualified freshman and sophomore students enter these courses without much risk.

Methodology

Data Source

The data used for analysis was the final course letter grades (including + or – designation) for individual students from the Fall 2015 to Fall 2019 semesters. The courses used were from the MEM curriculum that were in either the School of Engineering or School of Business. The data was provided by UConn's Office of Institutional Research and Effectiveness, where the student name was given a dummy ID to ensure confidentiality. Some further processing was performed to assign course numbers, student year, and course semesters to the data set. To simplify the analysis, each major was separated into one of four major categories as shown in Table 2. All engineering majors were designated as engineering, all business majors were designated as business, all MEM were designated MEM, and the remaining students were designated as Other. These designations were based on the stated major provided in the record; minors were not evaluated. Grade designations of AU, I, IF, N, NF, P@, W, S, U, XF, WAU, and X were removed and accounted for 4,223 records. These were removed as they are not part of the standard grading evaluations and are used for special designations. After cleaning the data (which included removing records with no grades or no major), 43,900 useable records were produced with a distribu-

Major	Category	Major	Category	Major	Category
Accounting	Business	Environmental Studies	Other	Music	Other
Acting	Other	Exercise Science	Other	Natural Resources	Other
African American Studies	Other	Exploratory	Other	Nursing	Other
Africana Studies	Other	Finance	Business	Nutritional Sciences	Other
Agriculture & Natrl Resources	Other	Financial Management	Business	Pathobiology	Other
Allied Health Sciences	Other	French	Other	Pharmacy Studies	Other
American Studies	Other	General Program in Art	Other	Philosophy	Other
Animal Science	Other	General Program in Music	Other	Physics	Other
Anthropology	Other	General Studies	Other	Physiology & Neurobiology	Other
Applied and Resource Economics	Other	Geography	Other	Political Science	Other
Applied Mathematical Sciences	Other	Geoscience	Other	Pre-Bachelor of Social Work	Other
Biological Sciences	Other	Health Care Management	Business	Pre-Communication Sciences	Other
Biomedical Engineering	Engineering	History	Other	Pre-Individualized	Other
Business Administration	Business	Horticulture	Other	Pre-Journalism	Other
Business and Technology	Business	Human Dev & Family Studies	Other	Pre-Kinesiology	Other
Business Data Analytics	Business	Human Rights	Other	Pre-Pharmacy	Other
Chemical Engineering	Engineering	Individualized	Other	Pre-Sport Management	Other
Chemistry	Other	Interdisciplinary	Other	Pre-Teaching	Other
Chinese	Other	Italian Lit & Cultural Studies	Other	Pre-Teachings Music Education	Other
Civil Engineering	Engineering	Journalism	Other	Professional Studies	Other
Coastal Studies	Other	Landscape Architecture	Other	Psychological Sciences	Other
Cognitive Science	Other	Linguistics/Philosophy	Other	Psychology	Other
Communication	Other	Linguistics/Psychology	Other	Real Estate & Urban Economic	Business
Computer Engineering	Engineering	Management	Business	Resource Economics	Other
Computer Science	Other	Management Information Systems	Business	Social Science-Sport/Leisure	Other
Computer Science & Engineering	Engineering	Marine Sciences	Other	Sociology	Other
Design/Technical Theater	Other	Maritime Studies	Other	Spanish	Other
Digital Marketing & Analytics	Business	Marketing	Business	Special Education	Other
Digital Media and Design	Other	Materials Science and Engr	Engineering	Speech, Language & Hearing Sci	Other
Ecology & Evolutionary Biology	Other	Mathematics	Other	Sport Management	Other
Economics	Other	Mathematics/Actuarial Science	Other	Statistics	Other
Electrical Engineering	Engineering	Mathematics/Statistics	Other	Structural Biology/Biophysics	Other
Elementary	Other	Mathematics-Actuarial-Finance	Other	Sustainable Plant and Soil Sys	Other
Engineering Physics	Engineering	Mathematics-Physics	Other	Theater Studies	Other
English	Other	Mechanical Engineering	Engineering	Turfgrass and Soil Science	Other
Environmental Engineering	Engineering	Medical Technology	Other	Undecided	Other
Environmental Science	Other	MGMT & ENGR for Manufacturing	MEM	Urban and Community Studies	Other
Environmental Sciences	Other	Molecular and Cell Biology	Other	Women's Gender & Sexuality Std	Other

Note. Each major was separated into one of four major categories with all engineering majors designated as Engineering, all business majors designated as Business, all MEM students were designated MEM, and all the remaining majors were designated Other.

Table 2. Rubric for assigning major categories

tion among the courses shown in Table 3. The courses are listed alphabetically with engineering highlighted in green and business courses highlighted in blue. Courses with less than 25 records for any major category were removed from the analysis. Table 3 confirms that there were enough students in each course for the analysis to be statistically relevant. The data was then analyzed in Microsoft Excel using the process outlined in the Data Analysis section.

Quantitative Data Analysis

The data analysis process started with the previously cleaned data and was performed for each course and major category using Microsoft Excel. Microsoft Excel was used due to the availability and ease of use. The first step was to do a simple count of the number of A through F grades. This count also included the "+" and "–" designations. Numerical values for these were calculated using the values for a four-point grade point average (GPA) scale. The values were calculated using the values of A = 4.0, A- = 3.7, B+ = 3.3, B = 3.0, B- = 2.7, C+ = 2.3, C = 2.0, C- = 1.7, D+ = 1.3, D = 1.0, D- = 0.7, and F = 0.0. Next, a count of the number of freshmen, sophomores, juniors, and seniors was performed. Finally, the grades earned for freshmen, sophomores, juniors, and seniors was calculated and for seniors the fall and spring semesters were separated. This data was organized for use in the data tables.

The first calculation performed was the GPA for each major category based on course data. This is based on the standard GPA that is used to assess one student over their

Count	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801
Business	1542	2125	2929	-	-	108	-	-	3455	-	-	-	-	3257	2827	2966	-	-	211
Engineering	126	-	-	2003	1721	2741	636	68	-	1217	205	883	841	-	-	-	1528	283	90
MEM	139	123	106	155	174	127	133	93	167	155	153	129	159	155	131	147	176	140	182
Other	4384	124	142	391	80	3235	28	-	211	155	-	-	-	232	63	117	155	-	77

Note. Engineering courses are highlighted in green and business courses are highlighted in blue. See Table 1 for complete course titles.

Table 3. An alphabetical list of courses and sample size (after cleaning) used for the data analysis

StDev	Average
Business	0.6
Engineering	0.7
MEM	0.7
Other	0.9
Average	0.7

Note. The analysis was performed after the letter grade was transformed into the corresponding numerical value.

Table 4. Standard deviation of the cGPA

entire undergraduate career, which generates an average grade earned over the entirety of the courses taken. This standard GPA was revised to analyze all the students over the time of a course, thus giving an average grade for all students in a course over the time analyzed. The GPA calculated was defined as the course grade point average and designated cGPA to separate it from the standard GPA for one-student over an academic career. This provided an average student success value for each course and major category using a standard 4.0 grade point scale.

Two calculations were performed next based on the count of grades. The first calculation was a percentage of A, A-, B+, B, B-, and <B- grades earned in each course by major category. Grades of less than B- were grouped together as they were generally a lower percentage of the scores. Next the percentage of A grades (%A's) and percentage of A minus grades (%A-'s) were added together to develop a key success factor (KSF). To further understand the KSF, it is helpful to understand what success in a course is. Going into a course, most students would set their definition of success as an "A" in the course. For this research, the definition of success was expanded to include an "A-". This is generally accepted as a successful grade – even if it is not the ideal grade. Because most scholarships and programs require at least a 3.0 grade point average, the concept of success was expanded to include the "A-" grade. Another reason for counting the A- as success is due to course load. Students may not have time to focus on earning an A grade and would define earning an A- during a challenging semester as a success. A second factor, a ratio of %A's to %A-'s, was calculated to help emphasize the number of students who were not only successful but also excelled in a course. This ratio is designated the excellence factor (EF). The higher this EF, the more students excelled. This provides a further breakdown of the KSF into high achievers.

The rationale for developing these equations relies on research that correlates student GPA to academic success. One study of overall college grade-point calculated a reliability of 0.93 (Beatty, Walmsley, Sackett, Kuncel, & Koch, 2015). Given that the availability of final course grades and the consistency of this data, the final course grades are not only a practical starting point but also a theoretically sound starting point. Final grades were given and stored in university databases for all students and for all the courses that were needed for this research. Thus, access to these grades was relatively simple. Grade point averages are a common assessment of student success (Brookhart et al., 2016) (Westrick, 2017), so an adaption of a measure (cGPA) based on GPA should allow for interpretation of student success. While GPAs are not effective at predicting future success (Brookhart et al., 2016), studies have shown that grades do predict school success (Beatty et al., 2015). Success factors such as Success at School Factor (SSF) (Bowers, 2011) are present in literature to provide a starting point for new novel analysis tools. The KSF and EF are final grade-based factors that have been created to measure academic success. The calculations used for this research were intentionally left as descriptive to provide an overview of past student success. Subsequent research is being completed by the author using machine learning for the prediction of student success. The results presented in this paper, along with the subsequent research, will provide an analysis that can be used to assess a dual-degree or combined program.

Tables were generated that separated grades by course and major categories with averages provided for further analysis. A difference between MEM and either engineering or business students is also provided in the tables to compare MEM student success directly to engineering and business student success. Data for students in the "Other" major category was included in the tables for completeness but is not directly discussed. In most cases, students in the "Other" major category did not perform as well as the major categories that are the focus of this research. This is an area that further research could explore to understand the reason for lower performance.

Error Analysis

Error was considered to determine the variation within major categories and between different major categories. The cGPA standard deviation was calculated for each major category and is shown in Table 4. To calculate the standard deviation, the letter grade was first transformed into the corresponding numerical value as outlined in the Data Analysis section. As shown in Table 4, there is not a significant difference between the major categories, indicating that comparison across them is valid. The average standard deviation of 0.7 reflects the fact that there were a range of grades achieved. This is expected, because not every student achieves the same grade. Since both the KSF and the EF are calculated from a count of recorded grades, the error in this value is not considered.

Results

Course Grade Point Average (cGPA)

One of the most used grade evaluation tools is the grade point average. For this analysis, a four-point scale was used for the calculation as outlined in the Analysis section. Table 5A shows the results of the cGPA for business courses. The averages and differences for the courses show that there is no significant difference between the cGPA for MEM and business. Engineering results were lower; however, engineering only had data for two courses, where engineering students received the lowest cGPA (2.8) for the intro accounting course. OPIM 3801, project management, was taken by all majors and will be discussed further in a separate section analyzing courses taken by all majors. Table 5B shows the results for the comparison of engineering courses. Again, the MEM students and the engineering students showed no significant difference in cGPA on average and no significant difference on a course level. Business students only participated in one engineering course, CSE 1010 – Intro to Computers for Engineers, where the cGPA was the same as MEM and engineering.

Key Success Factor (%A+%A-)

The KSF data, Table 5C and 5D, for both business and engineering courses produced results that show a slightly better success by the engineering and business students in their respective courses than the MEM majors. However, with a difference of -4% KSF average for business courses and a -5% KSF average for engineering courses, the data shows only a slight advantage for the business and engineering major categories. In the business courses, MEM students underperformed most in the business law course (BLAW 3175) and the introductory management course (MGMT 3101) – with a -12% each. The introductory accounting (ACCT 2001) and introductory marketing (MKTG 3101) courses also showed a decrease (-9% and -6% respectively) in performance for the MEM students. Only the introductory finance course (FNCE 3101) showed the MEM students over performing by 5% compared to the business students. When comparing the success of MEM students to engineering students in business courses, MEM students outperformed engineering students by 6% indicating a slightly better success for MEM. However, engineering only had data for two courses – ACCT 2001 – Principles of Financial Accounting and OPIM 3801 – Principles of Project Management. The engineering course data shows a similar KSF analysis with the business courses. There were two courses, ENGR 3215 – Industrial Quality Control (-15%) and ME 3227 – Design of Machine Elements (-14%) where engineers significantly outperformed the MEM students. The ECE 2000 – Electrical and Computer Engineering (-7%), ME 2233 – Thermodynamics (-6%), and the MSE 2102 – Material Science II (-6%) courses also showed significant difference between MEM and engineering. The only course where MEM students outperformed engineering students was MSE 2101 – Material Science I, and the

A.

cGPA	ACCT 2001	ACCT 2101	BLAW 3175	FNCE 3101	MGMT 3101	MGMT 4900	MKTG 3101	OPIM 3801	Average
Business	3.3	3.2	3.4	3.4	3.6	3.7	3.5	3.7	3.5
Engineering	2.8	-	-	-	-	-	-	3.7	3.2
MEM	3.1	3.3	3.3	3.6	3.6	3.7	3.4	3.7	3.5
Other	*2.8*	*3.2*	*3.6*	*3.1*	*3.6*	*3.8*	*3.4*	*3.4*	*3.4*
MEM-Bus	-0.1	0.1	-0.1	0.1	-0.1	0.0	0.0	0.0	0.0
MEM-Eng	0.4	-	-	-	-	-	-	0.0	0.2

B.

cGPA	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	ME 2233	ME 3221	ME 3227	ME 3263	MSE 2101	MSE 2102	Average
Business	-	-	3.1	-	-	-	-	-	-	-	-	3.1
Engineering	3.1	3.2	3.1	3.3	3.6	3.1	3.5	3.5	3.5	3.2	3.5	3.3
MEM	3.1	3.2	3.0	3.4	3.4	3.0	3.4	3.3	3.4	3.3	3.4	3.3
Other	*2.4*	*2.4*	*2.9*	*2.4*	-	*2.4*	-	-	-	*2.7*	-	*2.6*
MEM-Bus	-	-	0.0	-	-	-	-	-	-	-	-	0.0
MEM-Eng	0.0	0.0	0.0	0.0	-0.2	-0.1	-0.1	-0.2	0.0	0.1	-0.1	-0.1

C.

%A+%A-	ACCT 2001	ACCT 2101	BLAW 3175	FNCE 3101	MGMT 3101	MGMT 4900	MKTG 3101	OPIM 3801	Average
Business	51%	46%	52%	60%	72%	79%	53%	78%	61%
Engineering	33%	-	-	-	-	-	-	73%	53%
MEM	42%	46%	41%	65%	59%	78%	48%	76%	57%
Other	*33%*	*40%*	*65%*	*51%*	*70%*	*83%*	*52%*	*51%*	*56%*
MEM-Bus	-9%	1%	-12%	5%	-12%	-1%	-6%	-1%	-4%
MEM-Eng	8%	-	-	-	-	-	-	3%	6%

D.

%A+%A-	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	ME 2233	ME 3221	ME 3227	ME 3263	MSE 2101	MSE 2102	Average
Business	-	-	44%	-	-	-	-	-	-	-	-	44%
Engineering	45%	47%	41%	53%	66%	42%	53%	58%	62%	32%	60%	51%
MEM	43%	47%	37%	46%	52%	35%	49%	44%	58%	35%	54%	45%
Other	*17%*	*18%*	*39%*	*21%*	-	*22%*	-	-	-	*15%*	-	*22%*
MEM-Bus	-	-	-7%	-	-	-	-	-	-	-	-	-7%
MEM-Eng	-2%	0%	-4%	-7%	-15%	-6%	-4%	-14%	-4%	3%	-6%	-5%

E.

A/A-	ACCT 2001	ACCT 2101	BLAW 3175	FNCE 3101	MGMT 3101	MGMT 4900	MKTG 3101	OPIM 3801	Average
Business	2.8	2.2	1.6	2.9	1.7	1.9	1.0	1.2	1.9
Engineering	3.2	-	-	-	-	-	-	1.4	2.3
MEM	2.6	3.8	1.4	3.3	1.6	1.6	1.1	1.7	2.1
Other	*1.8*	*2.1*	*2.7*	*3.1*	*1.2*	*2.7*	*1.9*	*1.0*	*2.1*
MEM-Bus	-0.2	1.5	-0.2	0.4	0.0	-0.3	0.1	0.6	0.2
MEM-Eng	-0.6	-	-	-	-	-	-	0.3	-0.1

F.

A/A-	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	ME 2233	ME 3221	ME 3227	ME 3263	MSE 2101	MSE 2102	Average
Business	-	-	1.4	-	-	-	-	-	-	-	-	1.4
Engineering	2.6	3.7	1.5	1.4	2.8	1.8	0.8	1.6	2.4	1.2	2.8	2.1
MEM	1.6	2.4	1.1	1.1	0.6	1.4	0.5	1.4	2.8	1.7	1.5	1.5
Other	*1.4*	*1.8*	*1.8*	*0.2*	-	*0.9*	-	-	-	*0.5*	-	*1.1*
MEM-Bus	-	-	-0.2	-	-	-	-	-	-	-	-	-0.2
MEM-Eng	-0.9	-1.3	-0.4	-0.3	-2.2	-0.4	-0.3	-0.3	0.5	0.5	-1.3	-0.6

Note. Business (A, C, E) and engineering (B, D, F) – (blue = business; green = engineering). The darker shaded areas indicate higher values. Table 5A and 5B show the results of the cGPA which is based on a four-point system and averaged over the entire course for each major category. This is similar to the standard GPA that is used to assess one student over their entire undergraduate career. Table 5C and 5D show the results of the key success factor (KSF) which is the sum of A's and A-'s for each course. The KSF was calculated by this method because most students would consider success as an A or A- in a course. Table 5E and 5F show the results of the excellence factor (EF) which is a ratio of %A/%A-. The higher this EF, the more students excelled. This provides a further breakdown of the KSF into high achievers. This data shows that on average, MEM students performed comparably to their business and engineering peers for the cGPA and the EF. There was a decrease in the KSF; however, it was relatively small at -4% compared with business peers and -5% compared with engineering peers.

Table 5. Grade breakdown table for each course analyzed

difference was only slight at 3%. The only course with significant students from the business major category was CSE 1010 – Introduction to Computing for Engineers, and the business students outperformed both the MEM (7%) and engineering (3%) students. The students in the CSE 1010 from the business major were a mix of all business majors including accounting, business administration, finance, management and information science, marketing, and management. The analysis of the KSF data indicates that there are courses where the engineering and business major categories had a higher KSF than MEM; however, on average, these groups performed only slightly better than the MEM students.

Excellence Factor (A/A-)

When analyzing for high achievers using the EF, the MEM majors on average showed similar success – Table 5E and 5F. The excellence factor was developed to analyze those students who were successful in the course. The idea was to see which of these students achieved an A in the course and thus excelled. On average the MEM students earned a slightly higher average EF (0.2) than the business major category in the business courses. One outlier is ACCT 2101 – Principles of Managerial Accounting where the MEM students outperformed by an EF of 1.5. In the engineering courses MEM students slightly lagged behind the engineering students with an EF of -0.6. In ENGR 3115 – Industrial Quality Control the trend continued from the KSF where the engineers outperformed MEM (KSF -15%) and EF of -2.2. This shows that the MEM students who achieved success also did not excel as much as the engineers. MSE 2102 – Material Science II shows a similar trend where the KSF was -6% and the EF was -1.3. In ME 3227 – Design of Machine Elements where the MEM KSF was -14% the EF was only -0.3 indicating that those MEM students who were successful were equally high achieving. In contrast, for CE 3110 – Mechanics of Materials the KSF was equal for both groups; however, the EF favored the engineers (-1.3). This shows that the engineers excelled at a higher rate than the MEM students even with an equal success rate. Both ME 3263 – Sensors and MSE 2101 – Material Science I showed slightly higher EFs for MEM – 0.5 for each.

Courses with All Three Majors

There were three courses with students from all three major categories. These courses are ACCT 2001 – Principles of Financial Accounting, CSE 1010 – Introduction to Computers for Engineers, and OPIM 3801 – Principles of Project Management. While three courses cannot show a definite trend, an analysis of the courses can help identify potential trends. The average cGPA for each major category showed no significant difference. However, in ACCT 2001 business students earned the highest cGPA (3.3), MEM earned the second highest (3.1), and engineering students earned a significantly lower cGPA (2.8). This shows that, in this business course, the business students earned the highest grades, followed by MEM, and then engineering. When looking at the KSF for ACCT 2001 it shows the same pattern as the cGPA – business 51%, MEM 42%, and engineering 33%. CSE 1010 showed business with the highest KSF (44%), engineering was next (41%), and MEM last (37%). It was unexpected that business students would achieve a higher KSF than engineering students in an engineering course; however, this course is a computer course. Some business students focus on computers and computer-related technology, so those that take this course are likely strong already in computers and computer-related technology. The KSF for OPIM 3801 again shows business students on top (78%), MEM second (76%), and engineering last (73%). Before concluding that business students show the highest success rate, it needs to be noted that two of the courses with all three majors are in the business school and only one from engineering.

Analysis of the EFs indicate that a high KSF does not correlate to a high EF. In ACCT 2001 engineering students earned the lowest KSF (33%) but the EF was the highest at 3.2. Business and MEM had EF of 2.8 and 2.6 respectively. A similar trend shows in OPIM 3801 where the highest EF was for MEM (1.7), engineering students were second (1.4), and business students last (1.2). For OPIM 3801, business students earned the highest KSF (78%) but subsequently earned the lowest EF (1.2). This data shows that high success (KSF) does not correlate to excelling in a course (EF). While a small sample size, analysis of courses with all three major categories shows that there is not a relationship between the three factors used in the analysis.

Business	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	0%	4%	24%	-	-	12%	-	-	17%	-	-	-	-	21%	99%	22%	-	-	56%	28%
Junior	8%	67%	61%	-	-	17%	-	-	77%	-	-	-	-	75%	1%	77%	-	-	43%	47%
Sophomore	86%	29%	15%	-	-	29%	-	-	7%	-	-	-	-	4%	0%	1%	-	-	1%	19%
Freshman	5%	0%	0%	-	-	43%	-	-	0%	-	-	-	-	0%	0%	0%	-	-	0%	5%
Total	100%	100%	100%	0%	0%	100%	0%	0%	100%	0%	0%	0%	0%	100%	100%	100%	0%	0%	100%	

Engineering	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	21%	-	-	4%	24%	2%	70%	97%	-	20%	87%	93%	39%	-	-	-	26%	72%	71%	48%
Junior	36%	-	-	25%	65%	5%	26%	3%	-	30%	13%	7%	61%	-	-	-	56%	27%	29%	29%
Sophomore	38%	-	-	70%	11%	7%	4%	0%	-	49%	0%	0%	0%	-	-	-	18%	1%	0%	15%
Freshman	6%	-	-	1%	0%	85%	0%	0%	-	1%	0%	0%	0%	-	-	-	1%	0%	0%	7%
Total	100%	0%	0%	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	0%	0%	0%	100%	100%	100%	

MEM	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	2%	20%	81%	5%	25%	3%	41%	97%	75%	60%	96%	95%	98%	70%	100%	83%	20%	71%	55%	58%
Junior	51%	70%	19%	34%	72%	1%	59%	3%	25%	39%	4%	5%	2%	30%	0%	17%	68%	29%	43%	30%
Sophomore	44%	10%	0%	62%	3%	10%	1%	0%	0%	1%	0%	0%	0%	0%	0%	0%	12%	0%	2%	8%
Freshman	3%	0%	0%	0%	0%	86%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	

Other	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	4%	9%	44%	7%	18%	3%	21%	-	42%	11%	-	-	-	41%	100%	41%	19%	-	49%	29%
Junior	19%	41%	34%	28%	70%	7%	61%	-	51%	40%	-	-	-	46%	0%	55%	36%	-	44%	38%
Sophomore	69%	49%	21%	64%	13%	18%	18%	-	8%	48%	-	-	-	13%	0%	4%	43%	-	6%	27%
Freshman	8%	1%	1%	1%	0%	72%	0%	-	0%	1%	-	-	-	0%	0%	0%	2%	-	0%	6%
Total	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	0%	0%	0%	100%	100%	100%	100%	0%	100%	

Note. The tables first sorted by major category and then by course. The percentages indicate what percentage of students completed the course in the corresponding academic standing. An average for each academic standing is calculated in the last column. The darker shaded areas indicate higher values. This data shows that most students in the data set were juniors and seniors.

Table 6. Percent of students by year taking courses by academic standing

Impact of Other Courses

Course Completion Breakdown by Year

Another important aspect of course grades is the semester and combination of courses taken. Table 6 shows a breakdown by major category of the semester that each course was taken. As expected, most of the courses were taken in the junior or senior year. This is expected because the business school only accepts juniors and seniors; along with this, the engineering courses used for this analysis are generally upper-level courses that require prerequisites. CSE 1010 is the major exception as most of the MEM and engineering students completed this course in their freshmen years; business students generally completed the course later in their academic career. For the business courses, the MEM students were more likely to complete the courses later in their academic career than the business students.

cGPA by Year

An understanding of the impacts of cGPA by year is important to test if course success is dependent on the year that a student completes the course. Table 7 shows the cGPA by major category summarized for each year. The overall trend suggests that courses taken in the junior or senior year have no impact on grade. There is a slight reduction in cGPA for sophomore year – especially for the engineering students. Each major category showed a noticeable reduction in cGPA for freshman year. The data would suggest that students in their freshman year would be expected to earn a lower cGPA. This follows the logic that the courses used for this analysis are generally upper-level courses that require prerequisites and prior knowledge or experience that freshmen students have not acquired.

cGPA in Senior Year by Semester

The final analysis of other course impacts on grades was done to test the concept of the "senior slump." The senior slump is the idea that senior-year students will not work as hard their spring semester before graduation. Table 8 shows the data collected to test this theory. First, the overall cGPAs earned during senior year are provided for each major category. Then, the senior year fall and spring semester data were separated. The final row in the tables show the difference between the fall and spring semester. For the courses used in this analysis, there is no difference between the average cGPAs over the courses for any of the major categories. There are courses such as ECE 2000 for engineering students where the cGPA is lower (1.4 lower cGPA) during the spring semester, but that is compensated for by other courses (ENGR 3215 0.6 higher cGPA).

Conclusions and Impact

Conclusion

The results of this research show that MEM students achieved similar success when compared to the business and engineering students. The cGPAs showed no advantage for the single degree students over their MEM peers. There was a decrease in the KSF for MEM – -5% for business and -7% for engineering. This decrease in the KSF would be expected from a generalist degree, but the decrease is small. It could be argued that MEM students still showed significant success based on the cGPA values. The EF values for individual courses and on average were similar to KSF values in that there was some variation over courses. Results also show that, on average, the MEM students performed better than their business peers (0.2 EF). It was found that MEM students had higher EF in four of the eight courses – ACCT 2101 (1.5), FNCE 3103 (0.4), MKTG 3101 (0.1), and OPIM 3801 (0.2). For engineering, MEM students scored higher in two courses – ME 3263 (0.5) and MSE 2101 (0.5). However, on average, MEM students were not as successful with an EF of -0.6. These results indicate that MEM students were able to achieve high levels of success in the component degree courses. Future research could investigate the reasons for the variations identified in this research in the success factors for individual courses.

Business	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	3.4	3.2	3.5	-	-	3.4	-	-	3.2	-	-	-	-	3.6	3.7	3.5	-	-	3.7	3.5
Junior	3.2	3.2	3.4	-	-	3.5	-	-	3.5	-	-	-	-	3.6	3.5	3.5	-	-	3.7	3.5
Sophomore	3.3	3.3	3.5	-	-	3.3	-	-	3.6	-	-	-	-	3.7	-	3.3	-	-	3.2	3.4
Freshman	3.2	3.8	-	-	-	2.7	-	-	-	-	-	-	-	-	-	-	-	-	-	3.2

Engineering	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	2.8	-	-	3.0	3.2	3.2	3.4	3.6	-	3.2	3.5	3.5	3.5	-	-	-	3.2	3.6	3.7	3.3
Junior	2.7	-	-	3.2	3.2	3.0	3.3	4.0	-	3.2	3.4	3.3	3.5	-	-	-	3.2	3.4	3.7	3.3
Sophomore	2.9	-	-	3.1	2.8	3.2	2.9	-	-	3.0	-	-	3.0	-	-	-	3.0	2.8	-	3.0
Freshman	2.5	-	-	3.1	3.0	3.1	2.7	-	-	3.2	-	-	-	-	-	-	3.4	-	-	3.0

MEM	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	3.2	3.4	3.3	2.4	3.0	3.5	3.4	3.4	3.5	2.9	3.4	3.3	3.4	3.6	3.7	3.4	3.3	3.4	3.7	3.3
Junior	3.1	3.3	3.6	3.1	3.2	3.3	3.3	3.2	3.6	3.0	3.6	3.3	3.0	3.6	-	3.4	3.3	3.4	3.7	3.3
Sophomore	3.1	3.3	-	3.2	3.0	2.9	3.0	-	-	3.9	-	-	-	-	-	-	3.1	-	3.7	3.2
Freshman	3.2	-	-	-	-	3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	3.1

Other	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	2.7	3.3	3.6	2.8	2.8	3.2	2.5	-	3.1	2.3	-	-	-	3.7	3.8	3.6	2.9	-	3.4	3.1
Junior	2.7	3.1	3.5	2.2	2.3	2.9	2.5	-	3.1	2.5	-	-	-	3.6	-	3.3	2.9	-	3.5	2.9
Sophomore	2.9	3.2	3.5	2.4	2.5	2.9	2.2	-	3.1	2.3	-	-	-	3.6	-	3.3	2.5	-	2.8	2.9
Freshman	2.8	2.7	2.7	2.5	-	2.9	-	-	-	3.4	-	-	-	3.7	-	-	1.7	-	-	2.8

Note. The tables first sorted by major category and then by course. An average for each academic standing is calculated in the last column. The darker shaded areas indicate higher values. This data shows that the cGPAs for the Junior and Senior year students were the same. The Freshman and Sophomore students did show a decrease in cGPA of on average 0.22.

Table 7. The cGPA of students taking courses by academic standing

Business	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	3.4	3.2	3.5	-	-	3.4	-	-	3.2	-	-	-	-	3.6	3.7	3.5	-	-	3.7	3.5
Fall	4.0	3.1	3.4	-	-	3.4	-	-	3.2	-	-	-	-	3.6	3.7	3.4	-	-	3.7	3.5
Spring	3.2	3.3	3.5	-	-	3.5	-	-	3.2	-	-	-	-	3.6	3.7	3.5	-	-	3.7	3.4
Fa - Sp	0.9	-0.1	0.0	-	-	0.0	-	-	0.0	-	-	-	-	0.0	0.1	0.0	-	-	0.0	0.1

Engineering	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	2.8	-	-	3.0	3.2	3.2	3.4	3.6	-	3.2	3.5	3.5	3.5	-	-	-	3.2	3.6	3.7	3.3
Fall	2.5	-	-	3.3	3.4	3.3	3.4	3.0	-	3.1	3.4	3.5	3.5	-	-	-	3.2	3.5	3.7	3.3
Spring	2.9	-	-	2.8	3.0	3.1	2.0	3.6	-	3.3	3.9	3.5	-	-	-	-	3.2	3.6	3.7	3.2
Fa - Sp	-0.4	-	-	0.5	0.3	0.1	1.4	-0.6	-	-0.2	-0.5	0.1	-	-	-	-	0.0	-0.1	0.0	0.1

MEM	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	3.2	3.4	3.3	2.4	3.0	3.5	3.4	3.4	3.5	2.9	3.4	3.3	3.4	3.6	3.7	3.4	3.3	3.4	3.7	3.3
Fall	3.2	3.2	3.3	2.5	3.4	2.7	3.4	3.3	3.6	2.9	3.4	3.4	3.4	3.5	3.8	3.4	3.3	3.4	3.8	3.3
Spring	-	3.6	3.3	2.4	2.5	3.8	-	3.4	3.5	2.9	3.0	3.3	-	3.6	3.7	3.4	3.2	3.4	3.6	3.3
Fa - Sp	-	-0.4	0.0	0.1	0.9	-1.1	-	-0.1	0.1	0.0	0.4	0.1	-	-0.1	0.1	0.0	0.1	0.0	0.1	0.0

Other	ACCT 2001	ACCT 2101	BLAW 3175	CE 2110	CE 3110	CSE 1010	ECE 2000	ENGR 3215	FNCE 3101	ME 2233	ME 3221	ME 3227	ME 3263	MGMT 3101	MGMT 4900	MKTG 3101	MSE 2101	MSE 2102	OPIM 3801	Average
Senior	2.7	3.3	3.6	2.8	2.8	3.2	2.5	-	3.1	2.3	-	-	-	3.7	3.8	3.6	2.9	-	3.4	3.1
Fall	2.7	3.4	3.7	2.8	2.9	3.5	2.5	-	3.0	2.2	-	-	-	3.7	3.8	3.4	2.7	-	3.5	3.1
Spring	2.6	3.2	3.6	2.8	2.8	3.1	-	-	3.2	2.5	-	-	-	3.6	3.8	3.7	3.1	-	3.4	3.2
Fa - Sp	0.1	0.3	0.1	0.0	0.1	0.4	-	-	-0.2	-0.2	-	-	-	0.1	0.0	-0.3	-0.4	-	0.1	0.0

Note. The tables first sorted by major category and then by course. The first row shows the combined cGPA for the fall and spring semesters. The cGPA was then calculated for the senior year spring and senior year fall semesters. The final row in the tables show the difference between the fall and spring semesters. An average for each academic standing is calculated in the last column. The darker shaded areas indicate higher values. This data shows that on average there was no difference in performance based on semester.

Table 8. An analysis to test for the evidence of a senior slump in the spring semester of senior year

These insights are critical in helping students in STEM programs understand that they can be both successful business and engineering students. Before this study there was no clear evidence to show how these STEM students compared to their business and engineering peers. Some anecdotal evidence supported the idea that they were less successful than their single-degree peers. Other anecdotal evidence suggested that these STEM students were some of the highest achievers in their classes. Many professors in the MEM program have seen these students obtain quality jobs with high salaries. Post-graduation data suggests that graduates from this program are valued by employers and well-prepared for professional careers. With these quantitative results, these STEM students will be able to understand that they are achieving success both before and after graduation.

The three newly defined success factors used for the analysis demonstrate situations where different major categories achieved high success (KSF) but not the same level of excellence (EF) along with other combinations of the factors. Even with some relatively minor variation within courses, the overall averages for each of the success factors showed that MEM majors were comparable students to both engineering and business students. When the senior year cGPA was further separated by fall and spring semester, it was shown that the concept of senior slump did not exist for the analyzed courses. Nor was there any significant variation in the cGPA for junior or senior years, suggesting that students had the required knowledge to succeed in the analyzed courses in either year. Sophomores and freshmen had a drop of 0.1 to 0.3 in cGPA, as seen in Table 7, suggesting that the courses should be scheduled for later in the academic career but, if taken early, there would only be a small impact on success.

This research is an important first step in the assessment of dual-degree programs and other multidiscipline degrees. The motivation for this research was to address the perceived problem that dual-degree programs create generalists that are not proficient in the component programs. This is especially important in STEM fields, such as engineering, where there are established fundamentals that engineering students must know by graduation. If these fundamental skills are not provided in the curriculum, then the students can face negative perceptions in the workplace (Josephine Flemming et al., 2010). The results of this research directly address the concerns of employers and demonstrate that the dual-degree students studied do not have a significant deficit in fundamental skills. This lack of deficit was shown in the analysis of the cGPA, KSF, and EF values for MEM students, which showed little or no advantage for the component programs. These results are critical for all multidiscipline programs, as administrators can use these results to demonstrate the effectiveness of a dual-degree program or multidiscipline program. Subsequent research by the author predicting student success will complement the research in this paper and provide a powerful set of assessment tools for administrators.

Impact

Administrators are looking for new ways to create academic degrees/programs that are not only interesting for students but also have value for companies hiring these students. These include dual-degree programs along with similarly structured joint programs (Jones, 2020) (Hartford, 2013)(Sharma, 2021). However, there can be resistance to these dual-degree programs, as there might be perceptions that the curriculum will result in graduates who are weak in the individual component programs and lack a quality STEM education. Dual-degree programs can be perceived as inferior to their component single-degree programs due to fewer program specific courses and/or perceived lack of focus on a single program (Knight, 2011). This can happen when the programs are truncated to create balanced semesterly course loads. The results from this paper demonstrate that a dual-degree engineering and business program can produce comparable students that are successful in the combined programs.. This research is particularly relevant as it combines two programs (business and engineering) that have limited cross-over courses. Professionals considering hiring dual-degree, STEM graduates can use these results to understand that these students are capable in both component programs. This provides more incentive to hire these students, as they have a more diverse skill set than a single-degree graduate. Administrators who are considering creating a dual-degree STEM program can use this research as evidence that combining programs does not necessarily result in poor performance in the component degree or STEM courses.

Acknowledgements

The author would like to thank all the colleagues that work in the MEM program and their continued effort to support the MEM program.

References

Beatty, A. S., Walmsley, P. T., Sackett, P. R., Kuncel, N. R., & Koch, A. J. (2015). The Reliability of College Grades. *Educational Measurement: Issues and Practice, 34*(4), 31–40. https://doi.org/10.1111/EMIP.12096

Boston University. (2020). MS in Management Studies. Retrieved February 27, 2020, from http://www.bu.edu/msms-ga/?utm_medium=search&utm_source=googleadwords&utm_campaign=-msms&tfa_3=search&tfa_4=googleadwords&tfa_1=msms&gclid=CjwKCAiA7t3yBRADEiwA4GFlI2mBqt5xYTdj1XZNCnq2Fqtw05UGJYV1gwctE93x-C7sqWNgGRbw9vxoCUSkQAvD_BwE

Bowers, A. J. (2011). What's in a grade? The multidimensional nature of what teacher-assigned grades assess in high school. *Http://Dx.Doi.Org/10.1080/13803611.2011.597112, 17*(3), 141–159. https://doi.org/10.1080/13803611.2011.597112

Brookhart, S. M., Guskey, T. R., Bowers, A. J., McMillan, J. H., Smith, J. K., Smith, L. F., … Welsh, M. E. (2016). A Century of Grading Research: Meaning and Value in the Most Common Educational Measure. *Http://Dx.Doi.Org/10.3102/0034654316672069, 86*(4), 803–848. https://doi.org/10.3102/0034654316672069

Brown, F. S., & Mendelson, M. I. (2003). *Industry Supported Dual Master's Degree Program*. Retrieved from https://peer.asee.org/industry-supported-dual-master-s-degree-program

Ferrare, J. J., & Miller, J. M. (2020). Making Sense of Persistence in Scientific Purgatory: A Multi-Institutional Analysis of Instructors in Introductory Science, Technology, Engineering, and Mathematics (STEM) Courses. *The Journal of Higher Education, 91*(1), 113–138. https://doi.org/10.1080/00221546.2019.1602392

Franchetti, M., & Ariss, S. S. (2016). The Implementation of Senior Design Capstone Projects Combining Engineering and Business Students. In *Journal of STEM Education: Innovations and Research* (Vol. 17). Retrieved from https://www.jstem.org/jstem/index.php/JSTEM/article/view/2163

Grünwald, S., & Zenon J. Pudlowski. (2002). Double Degree Programmes in Engineering with Business, Commerce, Economics and Related Fields Offered by Australian Universities. *World Transactions on Engineering and Technology Education, 1*(1), 33–37.

Hartford, M. E. (2013). The MSW-MPA Dual Degree Program in Gerontology: A New Model for the Preparation of Social Work Administrators. *Http://Dx.Doi.Org/10.1080/00220612.1976.10671388, 12*(3), 51–58. https://doi.org/10.1080/00220612.1976.10671388

Harvard Business School. (2020). MS/MBA: Engineeering Sciences. Retrieved February 27, 2020, from https://www.hbs.edu/mba/academic-experience/joint-degree-programs/school-of-engineering-and-applied-sciences/Pages/default.aspx

Jang, H. (2015). Identifying 21st century STEM competencies using workplace data. *Journal of Science Education and Technology, 25*(2), 284–301. https://doi.org/10.1007/s10956-015-9593-1

Jelks, S. M. R., & Crain, A. M. (2020). Sticking with STEM: Understanding STEM Career Persistence among STEM Bachelor's Degree Holders. *The Journal of Higher Education, 91*(5), 805–831. https://doi.org/10.1080/00221546.2019.1700477

Jones, G. (2020). Growth of dual degree programs accompanies steady decrease in average age of GS student - Columbia Spectator. *Columbia Spectator.* Retrieved from https://www.columbiaspectator.com/news/2020/01/31/growth-of-dual-degree-programs-accompanies-steady-decrease-in-average-age-of-gs-student/

Josephine Flemming, R. Mahlinga Iyer, Shortis, M., Vuthalura, H., Ke Xing, & Bruce Moulton. (2010). Employers' Perceptions Regarding Graduates of Engineering Dual Degrees. *World Transactions on Engineering and Technology Education, 8*(3), 277–282. Retrieved from https://www.researchgate.net/publication/289803550_Employers'_perceptions_regarding_graduates_of_engineering_dual_degrees

Karimi, H., & Pina, A. (2021). Strategically Addressing the Soft Skills Gap Among STEM Undergraduates. *Journal of Research in STEM Education, 7*(1), 21–46. https://doi.org/10.51355/JSTEM.2021.99

Knight, J. (2011). Doubts and Dilemmas with Double Degree Programs. *Universities and Knowledge Society Journal, 8*(2), 135. https://doi.org/10.7238/rusc.v8i2.1067

Lehigh University. (2020). Integrated Business & Engineering. Retrieved February 27, 2020, from https://engineering.lehigh.edu/academics/undergraduate/interdisciplinary/integrated-business-engineering

McGunagle, D., & Zizka, L. (2020). Employability skills for 21st-century STEM students: the employers' perspective. *Higher Education, Skills and Work-Based Learning, 10*(3), 591–606. https://doi.org/10.1108/HESWBL-10-2019-0148

Milne, R. J., & Zander, A. K. (2012). Operations Research Capstone Courses for Business Majors with Analytical Backgrounds. *INFORMS Transactions on Education, 13*(1), 2–9. https://doi.org/10.1287/ited.1120.0091

National University of Singapore. (2020). Double Degree Programme in Engineering & Business Administration. Retrieved February 27, 2020, from https://www.eng.nus.edu.sg/undergraduate/double-degrees/double-degree-programme-in-engineering-business-administration/

Ngo, C. (2020). Dual Degree vs. Double Major: What's the Difference? | BestColleges. Retrieved October 13, 2021, from Best Colleges website: https://www.bestcolleges.com/blog/dual-degree-double-major-difference/

Nguyen, D. Q. (1998). The Essential Skills and Attributes of an Engineer: A Comparative Study of Academics, Industry Personnel and Engineering Students. *Global Journal of Engineering Education, 2*(1), 65–75. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.124.1502

Saunders, L., L. Ken, & Saunders, J. G. (2004). House of Quality Assessment of Business Skills Required by Manufacturing Engineering Graduates. *International Journal of Engineering Education, 20*(5), 777–786.

Scala, N. M., Tomasi, S., Goncher, A., & Bursi, K. M. (2018). Motivation and analytics: Comparing business and engineering students. *Transactions on Education, 19*(1), 1–11. https://doi.org/10.1287/ited.2017.0187

Sharma, Y. (2021). International dual and joint degrees to get green light. *University World News*. Retrieved from https://www.universityworldnews.com/post.php?story=20210226145106838

Swearengen, J. C., Barnes, S., Coe, S., Reinhardt, C., & Subramanian, K. (2002). Globalization and the undergraduate manufacturing engineering curriculum. *Journal of Engineering Education, 91*(2), 255–261. https://doi.org/10.1002/j.2168-9830.2002.tb00700.x

Todd, R. H., Red, W. E., Magleby, S. P., & Coe, S. (2001). Manufacturing: A Strategic Opportunity for Engineering Education. *Journal of Engineering Education, 90*(3), 397–405. https://doi.org/10.1002/j.2168-9830.2001.tb00619.x

University of Connecticut. (2020). MBA/MENG Dual Degree. Retrieved February 27, 2020, from https://masterofengineering.uconn.edu/mba-meng-dual-degree/?gclid=CjwKCAiA7t3yBRADEiwA4GFlIzte_ep0-bTY11eEK6P81FlQ_qBt44vZfUJ-1tnMWUDh-vc9FVMxBphoCjA4QAvD_BwE

University of Pennsylvania. (2020). Jerome Fisher Program in Management & Technology. Retrieved February 27, 2020, from https://fisher.wharton.upenn.edu/

Walczak, M. M., Ziegler-Graham, K., Bosak, E. B., Henry, K., Rice, K., & Richards, M. (2020). Course Taking Patterns and Pathways Through STEM: A Case Study Using Individual-Level Institutional Data for Program Assessment. In *Journal of STEM Education: Innovations and Research* (Vol. 20). Retrieved from https://www.jstem.org/jstem/index.php/JSTEM/article/view/2396

Wang, X., Lee, Y., & Wickersham, K. (2019). Exploring the Relationship Between Longitudinal Course-Taking Patterns and In-State Transfer Into STEM Fields of Study. The *Journal of Higher Education, 90*(2), 272–297. https://doi.org/10.1080/00221546.2018.1488210

Westrick, P. A. (2017). Reliability Estimates for Undergraduate Grade Point Average. *Http://Dx.Doi.Org/10.1080/10627197.2017.1381554, 22*(4), 231–252. https://doi.org/10.1080/10627197.2017.1381554

Craig A. Calvert, PhD, MS-BAPM, CHO is an Assistant Professor-in-Residence in the Operations and Information Management Department at the University of Connecticut. As a co-director of the Management and Engineering for Manufacturing (MEM) program, he oversees the education of around 170 students. The MEM program is a dual-degree STEM program combining business and engineering with a focus on manufacturing. His teaching and research interests are in STEM education, supply chain management, sports analytics, and project management. He is also the 2020 winner of the Innovation in Teaching Award from the UConn School of Business