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Assessing the Impact of Student Choice of Electives

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Dr. Barton's research focuses on the development of approximate closed form solutions for linear self-adjoint systems, those that govern the responses of composite structures, and the analysis of dynamic systems. He has published over 60 journal and conference articles on these topics. Dr. Barton has mentored numerous midshipmen through independent research projects and has directed two Trident Scholars, the Naval Academy's flagship research program.

Dr. Barton is actively involved in curriculum innovation and program assessment. He chaired ASME's Committee on Engineering Education and served as a member-at-large on the Executive Committee of the Engineering Accreditation Commission of ABET. Currently, he serves on ASME Foundation Board, NACME Board and a Trustee on the Board of Missouri Science and Tech, MS & T. Dr. Barton holds a professional engineering license in the State Maryland.

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Abstract

During the 2019-20 Academic Year, the Department of Mechanical Engineering revised its requirements to implement a more personalized curriculum model. Instead of mandating which technical courses are available for students to select to satisfy their electives requirements, students are allowed to take any upper level courses offered at George Mason University. The background and discussion that led up to this decision is presented as well as an inventory of choices students actually selected after the change went into effect.

Keywords

Electives, Curriculum, ABET Criteria

Background

Numerous efforts have been made to articulate what engineering students should learn to be successful in their future careers. Two models which immediately come to mind include the T Shaped model, identified as the latest version of the Renaissance man, and the hybrid model which is the intersection of technology & liberal. arts, [1,2]. The latter emphasizes that successful career-ready engineers need both technical depth in a single field while having intersectional competencies that lead to greater collaboration and innovation. One study by AACU has noted that although a broad skillsets matters, mindset and personal aptitudes play just as an important role in career success as well[3]. Moreover, ASME Vision 2030 was launched to help define what mechanical engineers should be able know and do upon entering the workforce. Findings from that study suggest that in addition to technical knowledge, students need to strengthen problem solving skills, communication skills, and develop a systems level perspective[4]. The study also shows a significant difference in how graduates, educators, and employers assess various strengths and weakness of recent ME graduates. Ultimately, this study recommended that ME programs should increase flexibility in its curriculum[5].

There are no shortages of recommendations on what changes can be made to engineering education in general. Mechanical engineering curricula are surprisingly similar and rigid to meet requirements of mechanical and thermal system design required by ABET. Most mechanical engineering educators emphasize technical skills throughout their programs while paying less attention to the boundary crossing competencies, mindset, aptitudes, and perspectives being suggested by employers. For example, an inventory of ME curricula nationwide performed in the spring of 2018 revealed that the average number of credits required for graduation is 126; the average curriculum required 28 basic math and science credits with 8 additional elective credits of basic math and science; 49 mechanical engineering credits with 17 additional credits of technical/ME elective; and 17 credits for core/liberal curriculum and composition and 7 credits

were free electives. More than 52% of the degree requirements rest solely in the both required courses and technical ME electives.

Motivation

A broad discipline in content, studying mechanical engineering is one such program that can lead to a career in many existing and emerging fields. The choice of career is highly personal and is likely to be driven by student's diverse passions and aspirations. Requiring students to take additional technical courses to develop additional technical skills may be met with diminishing returns. Our belief is that the required courses are both necessary and sufficient to students for the practice of engineering.

From personal experience running prospective student events, orientations, and our departmental advising program, many students interested in the mechanical engineering degree are often conflicted at application or have changing interests as they learn more about the field and career opportunities. This can leave them feeling as if they need to pursue multiple majors, minors or accelerated programs that allow for both the completion of bachelor and master's degrees. Students may also desire these additional credentials to set themselves apart from their peers in a competitive job applicant pool. By allowing students choices in their curriculum, specifically in the selection of their electives, our department believes that *we reduce the need for additional programs and increase the impressions of readiness for the workforce*. For those that still insist on pursuing an additional program, this change removes an additional hurdle to completing it.

Reluctance to make this change was also voiced during our initial discussions. Some faculty were concerned that this would result in less ME electives being offered and a "watered-down" curriculum. This would threaten the ability of faculty to create and offer electives in their areas of expertise. The counter argument was that *we should be offering electives that students want to take*. The idea of a prescriptive, parental model of teaching and learning is fast being replaced by one based on collaboration and coaching.

Some faculty were also concerned that students would take the "path of least resistance" and select the easiest courses available. While our institution has a large number of non-traditional students, the counter argument was that all *students should be treated as adults and as partners in their learning*. Students are investing their time and money into their academic careers. Faculty can offer advice and our suggestions, but it's ultimately the student's decision.

In addition, faculty were concerned that students have too few credits already, 121 total. Some advocated for additional required coursework which would reduce the number of electives or to increase the total credits. Compared with degree requirements of schools sampled in our survey, we are 5 credits below the 126 credit average; more than 10% of ME programs required in excess of 130 credits. The debate over college affordability has started in State Houses nationwide and many are pushing to cap BS degrees at 120 credit hours. As the issue of college affordability is at the forefront of engineering education discussions, *allowing more flexibility in course selection and application can make an engineering degree more attainable*. Each additional credit requires additional time and money to complete, and at our institution, there is pressure to make degrees more accessible with less barriers to completion.

Institutions that see a large population of transfer students, such as ours, will have further challenges on retention and persistence which are often created by ill-defined pathways, lack of advising support and credit loss upon matriculation to a new program. Figures as high as 43% have been cited for credit lost as a result of transferring to a new University[6]. Credit loss is particularly impactful on the academic careers of engineering students who may decide to change majors after their 1st or 2nd year. Upper level courses that do not meet a degree requirement can be applied to the new elective requirement for these students.

Policy

The final policy that was adopted became effective in the 2020-21 catalog year. Students will no longer be required to select 12 credits from a list of technical courses but can choose 12 credits of coursework offered at the 300 level and above. Existing students can be grandfathered into this policy without penalty since all previous technical electives were offered at the 400 level.

With the new policy in place attention to its implementation required careful consideration. For instance, elective options cannot be "double counted" for other required ME courses (i.e. Heat Transfer) or other university requirements (i.e. Advanced Composition). They may be "double counted" for minors, double majors, and bachelor's accelerated master's (BAM). Minor students must pay attention to the unique credit requirement where 8 credits must only count towards the minor. BAM students can count 500 and 600 level courses towards their undergraduate elective requirements.

While any course at George Mason University was initially proposed, upper level courses were specified as the University requires 45 credits total to be at the 300 level or above. Any student taking all 12 elective credits and all of their Core elective requirements at the 100 or 200 level would not meet this threshold as ME only mandates 41 upper level credits. A less restrictive policy allowing some lower level courses would have complicated the communication and subsequent advising required to support the policy.

Actions to Implement

The genesis and motivation for this policy largely came from the department chair during the 18-19 academic year. There were both formal and informal nudges to implement the change that did not result in definitive action. This led to an awkward exchange during an advisory board meeting in Spring 19. The new policy was given fresh urgency in Fall 19 when a faculty meeting was devoted to the topic. The result was department buy in that the idea should be pursued along with a formal policy and a plan to implement it.

An opt in process was suggested where students would propose the four courses they wished to take along with a letter, addressed to their advisor, which documents a strong personal interest in the proposed courses or a substantial connection to the mechanical engineering major. Students would then meet with their advisor to discuss the proposal and seek approval. The student's advisor would send the form to the Director of the Mechanical Engineering Undergraduate Programs for final approval. In the semester immediately prior to graduation, students would meet with the director to submit the university substitution forms which would replace the technical electives.

The proposal was not perfect but the faculty supported it. Upon presenting it to the department chair, the proposal was rejected. There was a strong feeling that this decision should ultimately be up to the students and additional barriers to its adoption should not be accepted. There was strength in their conviction that this was the right move and the department chair invested their personal capital in having the department adopt it.

The policy below was written up and entered into George Mason University's catalog software to be implemented into the 20-21 catalog. It was approved through the college curriculum committee, somewhat quizzically, and the university's undergraduate council.

The next step was to raise awareness and share the changes with the student body. A brief announcement was made through the department listserv with an invitation to attend a townhall presentation in February 2020. The department gave a detailed presentation on the elective policy change as well as other curriculum changes and department initiatives.

Advising such a decision with a large range of options and caveats was not neglected. Faculty advisers and students were provided a document that contained a number of suggestions centered around themes such as Energy and the Environment, Health, Security, Joy of Living, Immersion in the Mason Core, and Interdisciplinary. The course options were largely free of restrictions and pre-requisites were met by either required courses or Mason Core electives. Sample schedules, advising documents, and marketing materials were updated as well.

Students were also advised that they will need to research their options. Some courses will have pre-requisites, major/minor restrictions, or have limited offerings. Advisors were not responsible for finding options the student's found interesting and should recommend the ME electives if an attractive option was not available.

To take advantage of the new elective policy, students had to first learn about it and then update to a new catalog year. A vast majority of students are now in catalog year as of Fall 2022 but this is a result of a steady stream of catalog year updates requiring a form, graduations from older catalog years, and new student matriculation.

ME Elective Offerings and Enrollment

One of the initial concerns was how this would impact the ability of the department to offer ME electives. Figure 1 attempts to show the impact of this policy. Seniors are defined as students who have earned more than 90 credits at the start of the semester. Many of the ME electives are restricted to senior standing, though some exceptions are made, and the electives are shown in the 4th year of the sample schedule. The number of electives offered indicates how many distinct sections were offered that semester. The number of electives is mostly dictated by enrollment as sections with fewer than 12 were typically cancelled and students encourage to register for other electives. Total elective enrollment is also shown as not all seniors by credit count are taking electives. The enrollment per elective metric is introduced to help relate enrollment to the number of electives offered. In Fall 2022 only 6 electives were offered but they have healthy average enrollments of 21students whereas compared to the Spring 22 semester which had 10 electives offered but a more modest average enrollment of 13.8 students. Finally, as headcounts

and enrollments varied year over year, the ME electives per senior metric is also introduced to relate these two variables.

	Unrestricted Elective Policy ←					→ Technical Elective Policy					
	Fall 22	Spring 22	Fall 21	Spring 21	Fall 20	Spring 20	Fall 19	Spring 19	Fall 18	Spring 18	Fall 17
Senior Headcount	152	*174*	143	170	139	138	136	142	119	107	79
# of electives offered	**6**	***10***	**8**	**9**	**10**	**7**	**8**	**6**	**9**	**7**	**5**
Total Elective Enrollment	*126*	*138*	145	157	143	135	162	124	147	124	68
Enrollment per Elective	***21***	***13.8***	***18.1***	***17.4***	***14.3***	***19.3***	***20.3***	***20.7***	***16.3***	***17.7***	***13.6***
ME Electives per Senior	**0.83**	**0.79**	**1.01**	**0.92**	**1.03**	**0.98**	**1.19**	**0.87**	**1.24**	**1.16**	**0.86**

Figure 1. ME Electives and Enrollment over time

In general, there is some natural variation from year to year. Student interests vary as do the availability of full time and adjunct faculty to offer them. In academic year 21-22 an aerospace concentration was created where students have the option to take all of their 300/400 electives in this topic and earn this credential on their transcript. In general, it was expected that all of the bolded metrics in Figure 1 could decrease with greater adoption of the unrestricted elective policy.

Electives offered between Fall 17 and Fall 22 are listed here with the numbers in parentheses indicating the number of sections and combine enrollment: Fatigue Analysis (3-47), Composite Materials (2-35), HVAC Design (4-72), Renewable Energy Engineering (5-95), Systems Dynamics (4-53), Finite Element Analysis (5-76), Energetics (4-99), Computer Aided Design (7-156), Project Management (6-98), Introduction to Astronautics (6-125), Spacecraft Subsystems (4-60), Space Systems Propulsion (5-74), Aeronautics I (5-108), Aeronautics II (2-29), Aircraft Propulsion (1-21), Mission Analysis (1-13), A Seat at the Table (1-13), Advanced Technology Vehicles (1-13), Applied/Intro to Optimization (4-78), Building Systems (2-22), Engineering History & Ethics (1-15), Advanced Materials (1-19), Nanotechnology (2-36), Advanced Solids (2-32), Vibrations (1-22), and Machine Learning (2-40)

Unrestricted Policy Adopters

The department was also interested to see, of the students that adopted the new policy or had the option to take any upper level course at the university, how many did so? and what did they take? After the policy was implemented analysis were taken of the graduates in each academic year that had an eligible catalog year. In 20-21 and 21-22 about two thirds of the electives used for the unrestricted electives were ME courses. The main difference here is that many of the 20-21 graduates had already taken 1 ME elective prior to the introduction of the policy or learning of it.

	20-21 Graduates	21-22 Graduates	In Progress
# Eligible Students	35	47	110
Total Electives	146	201	310
ME Elective taken prior to Fall 2020	*14%*	*3%*	*3%*
ME Elective taken Fall 2020 or after	*53%*	*65%*	*48%*
Extra ME Elective not required for graduation	*3%*	*6%*	*2%*
Used towards minor requirement	*5%*	*3%*	*5%*
Used towards 2nd/double major requirement	*0%*	*1%*	*3%*
Unrestricted Elective taken prior to Fall 2020	*9%*	*3%*	*8%*
Unrestricted Elective taken Fall 2020 or after	*16%*	*17%*	*30%*
# Minors	6	3	10
# Double Majors	0	1	3
Average # of Credits at Graduation/Current	130	142	109

Figure 2. Elective category analysis

With only two full years of data at time of the writing of the article, many of the trends and expectations are not established yet. For instance, it was expected that the average credits at graduation would reduce but it actually increased for 21-22 graduates. It was also expected that the number of double majors and minors would increase proportional to the percentages of students in the program in Spring 2020. In 19-20 for instance, 55 students graduated, 1 was a double major and there were 4 minors.

It was also of interest to the authors to see where the policy was taking the program. An analysis of all current students in the major indicated that 110 of the 398 had credit for at least one elective. The average student in this population had 3 electives courses already completed and about half of those were from outside of the ME department. This is a significant increase which could impact the department offerings in future semesters.

To give an idea of what students were taking, the entire dataset of courses was reviewed. The most popular choices of courses outside of ME were HEAL 331 – Men's Health (9), STAT 344 – Probability and Statistics for Engineers and Scientists (6), STAT 346 – Probability for Engineers (5), GCH 300 - Introduction to Public Health (5), MBUS 304 - Entrepreneurship: Starting and Managing a New Enterprise (5), MBUS306 - Managing Projects and Operations (4), SYST460 - Introduction to Air Traffic Control (4), CONF 340 - Global Conflict Analysis and Resolution (4), GGS302 - Global Environmental Hazards (4), CRIM 400 - Applied Criminal Psychology (4), MATH301 -Number Theory (4), 10 courses (3), 23 course (2), 98 courses (1).

Conclusions

Anecdotally, from a number of advising meetings with students and conversations with other faculty, many students are taking electives for reasons such as needing to be a full-time student. This is a major concern when your financial aid, on campus housing, or visa depend on it. Without the new policy these credits would likely be wasted. The complex, pre-requisite structure in engineering programs such as ours can also be a barrier. Yearly offerings of resource intensive courses such as labs and senior design is another example.

One impact of the policy change may actually result in growth of the program which could offset some enrollment declines. The flexibility in the curriculum is especially student centric and could widen the application of the degree. Students that select courses that enhance their boundary crossing competencies, mindset, aptitudes, and perspectives may be more valued by employers creating a value proposition for students and the department.

Having a student population with unrestricted choice has also led the department to think more strategically about what we are offering. Sustained student interest in aerospace related electives have resulted in special topics courses earning permanent course numbers and consistent offerings. This in turn has resulted in the establishment of an Aerospace Engineering Concentration which has in turn helped ME elective enrollment. Further concentrations, minors, and certificates can attract new students and retain interest in the ones we already have.

Is the policy change a success? It's difficult to say at this point. The department so far has not offered significantly less sections of electives but is certainly losing some tuition revenue to other departments. George Mason University as a whole is neutral as the students taking courses in one department vs the other has no benefit. It is easy to argue that the increased choice for the students is a win for them. Harder to measure but equally important is how these students fare after leaving George Mason University. The hope is that they will be more satisfied and more successful as a result.

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