AC 2012-4666: ENROLLMENT AND PERSISTENCE OF FIRST-YEAR STUDENTS IN A NEWLY ACCREDITED ENGINEERING PROGRAM

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Enrollment and Persistence of First-Year Students in a Newly Accredited Engineering Program

Abstract

This paper examines the enrollment and persistence trends of first year students in recently accredited electrical and mechanical engineering programs at a predominantly undergraduate-oriented non-research intensive university where the programs were created from existing technology programs. For the first six years of the programs, transcript information and student surveys for students enrolled in an introductory engineering course were analyzed. Quantitative analysis was performed on the levels of student interest and math preparedness upon enrollment in the introductory course, and within-program and within-university persistence was quantified and compared to math level and grade earned in the introductory course. Enrollment in the introductory course is growing at an acceptable rate. However, demographics are shifting towards students who are unprepared to complete Calculus I simultaneously with the introductory course. Furthermore, for the underprepared math students, persistence is very poor (10% of trigonometry and algebra students, 27% of Precalculus students), but for students on-track in math, persistence is much better (28% of Calculus I students, 63% of post-Calculus I students). Lastly, a Precalculus co-requisite with the introductory course may reduce enrollment by 18%, but should only reduce number of majors by 5% or less. Until now, the programs have relied on a convenience sample of students with minimal program promotion or recruitment. However, focus should be directed at recruiting and retaining students who are prepared to enroll in Calculus, or at least Pre-calculus. Results of this study may be informative for universities looking to begin engineering programs.

1. Introduction

First-year persistence is a concern for all engineering programs. Nationally, only half of incoming freshmen with declared interest in engineering actually graduate with an engineering degree; most of the attrition occurs from first to second year.[1-4] There have been many studies into persistence rates, indicators and contributors to persistence, and improved pedagogy and resources to encourage persistence.

One of the difficulties in disseminating the persistence research is the variety of programs, curriculum, and student body characteristics. For example, what influences a cohort at a large engineering program with stringent (engineering-specific) admission requirements may not relate to a cohort of students in a smaller program without specific admission requirements. Likewise, statistics, demographics, and methods of a smaller program may not scale to a larger one. Thus there is a need for persistence analysis at a variety of institutions.

This paper looks at enrollment and persistence in small, newly accredited electrical and mechanical engineering programs at the historically liberal arts Central Michigan University (CMICH). It analyzes longitudinal data of first-year students' demographics and persistence from the first six years of the program, and discusses some of the challenges and lessons learned along the way. The hope is that similar universities looking to begin engineering programs

(possibly from existing engineering technology programs) can use the results to better understand their student body and thereby increase the likelihood of subsequent persistence. Within the text, three lessons are highlighted because of their importance to CMICH (and similar) programs.

2. Background

2.1 Overview of Central Michigan University's Engineering Program

The engineering programs at CMICH are relatively new. CMICH began offering courses in mechanical and electrical engineering (BSME and BSEE) in 2004, and graduated its first engineering students in 2007. Both programs have since been ABET accredited.

The two programs are housed in the School of Engineering & Technology (SET), in the College of Science & Technology (CST). The school is a broad collaboration of engineering, engineering technology, and technology programs, offering degrees in Construction Management (CM), Electrical Engineering (EE), Mechanical Engineering (ME), Mechanical Engineering Technology (MET), Industrial Technology Management: Manufacturing Technology (ITM-Man), and Industrial Technology Management: Mechanical Design (ITM-MD).

The engineering programs at CMICH are also traditionally structured. During the years of this study (2005-2011), the programs did not have program-specific admission requirements. Students are expected to take the introductory course (EGR120) during freshman year, along with the required math, physics, chemistry, and computer science courses. The second year begins the multiple engineering courses, with the "gateway" courses of Engineering Statics and Circuit Analysis I. The number of engineering majors is approximately 40 per year.

EGR120 is offered in both fall and spring semesters, with 76% of the students taking the course in the fall. The course currently has no prerequisites or co-requisites. For the first three years, the course was taught as one section; starting in the fourth year, it was broken into smaller multiple sections to enhance professor-student interaction and student learning. EGR120 is lecture-based and focuses on introducing students to engineering topics, projects, and the field, rather than teaching the basic math, science, or engineering material. With the recent switch to multiple sections, the course is taught round-robin-style with teaching blocks of electrical engineering (with a electrical professor), mechanical engineering (with a mechanical professor), engineering laboratories (with a technology professor), general engineering and two-week robotics project (with electrical or mechanical professor), and simultaneous two-week large project (with each professor). The mechanical and electrical blocks each include several single-day projects and labs, while the general engineering block includes upperclassman, student group, and alumni speakers to better EGR120 students' understanding of engineering both at CMICH and in the workforce.

EGR120 has consistently drawn a relatively higher, and growing, enrollment each year (currently around 170 students). The course is required by EE and ME students, but the current persistence

rate of the students is low when compared to literature. The vast majority of EGR120 students do not stay in engineering or in the School.

2.2 Relevant Research

There have been many studies on freshman engineering students' demographics and indicators of persistence, including a range of persistence rates. For example, Besterfield-Sacre *et al.*[3] (Univ. of Pittsburgh) found that students who left engineering in good academic standing had different views of engineering from the start: less interest, lower appreciation of the profession, less interest in math and science, and less confidence of success. Data in their paper show freshman persistence rates of 78-80%. Godfrey *et al.*[5] (Australian universities) examined the characteristics and timing of student departure from engineering and found students with some prior study were more committed to finishing engineering and generally persisted. Similarly, Budny *et al.*[6] (Purdue) studied transcripts and found freshman persistence of 64%, with 22% attrition from the university entirely. They also found correlations between persistence and math competency, first semester GPA, success and grade of first semester math course, and their Counselor-Tutorial program.[7] Ohland *et al.*[8] (nine large southeastern universities) found that GPA was not an indicator of attrition, but it was an indicator of destination – students with low GPAs migrated towards business-related majors while students with high GPAs tended to choose the sciences. More recently, they used survival analysis to understand the loss of students from engineering, and found differences in survival based on gender, ethnicity, SAT math, and SAT verbal scores.[9] Elsewhere, an engineering graduation rate of 45-54% is reported.[10] For NC State specifically, Ohland and colleagues[11] describe the effects of several curriculum changes that first only delayed, but after further revision decreased, attrition. Meanwhile, Tripplett and Haag[4] (ASU) analyzed demographics and show a freshman persistence rate of 74%.

Another large vein of research has been resources and programs to improve persistence. For example, Fortenberry *et al.*[1,9] (Colorado-Boulder) found a first-year projects course increased freshman persistence from 78 to 86%. Likewise, Seybert[13] (PSU Surveying) and Tezcan *et al.*[14] (SIU) each found that introductory courses raised freshman persistence from 54 to 76%, and to 65%, respectively. Baxter and Yates[15] (USC) discuss incorporating a freshman-level advising office and seminar series, and saw freshman persistence grow from 85% to 91%, while Meyers *et al.*[16] (Notre Dame) did not see improvement of students' comfort or adjustment from a student-based mentoring program. Finally, Dudeck and Grebski[17] (PSU) discuss combining freshman ET programs, and cite a low 30% freshman engineering persistence, with around 63% attrition to a non-engineering related major.

Surprisingly, very little data exist to document the start-up of engineering programs. Peterson[18] (Western Michigan) has described the development of an off-campus manufacturing engineering program from an established on-campus degree program. Additionally, Director *et al.*[19] (Carnegie Mellon) have published on the transition from traditional electrical and computer engineering as separate degrees to the introduction of an interdisciplinary degree in electrical and computer engineering.

CMICH's programs are unique when compared to those above. With respect to age, CMICH's programs are newly accredited; the programs cited above are well established. With respect to freshman persistence rates, CMICH is on the low end: 27% versus the range of 30% to 91% cited above. With respect to technology programs, CMICH is most similar to Purdue (64%) and PSU (30%). However, with respect to size, ASU (74%) or PSU Surveying (76%) seems more appropriate. In this sense, the lessons presented here fill a gap in the persistence literature especially in terms of young engineering programs.

3. Methods

Data were collected for six years in two forms: transcript information and brief in-class surveys. The six years correspond to twelve semesters: six fall semesters and six spring semesters. Here, a semester is referred as the academic year with a "F" or "S" for fall or spring; *e.g.*, the last semester examined was the spring of the 2010-2011 year, or "1011S".

The transcript information was collected for EGR120 students from 0506F to 1011S, from current transcripts. Data include:

- First semester at CMICH
- Graduation semester (if it exists)
- Math level – highest math course taken at CMICH before or during the EGR120 semester, including grade. The MathLevel was grouped into five categories: Post-Calculus (higher than Calculus I), Calculus, Precalculus, Pre-Precalculus (*e.g.*, trigonometry, algebra), and Unknown (no math taken at CMICH).
- EGR120 grade
- Engineering Statics grade (if it exists)
- Circuit Analysis I grade (if it exists)
- Current signed major – at CMICH, students may sign a Major (binding agreement) once eligible, or an Intent to Major (non-binding) at any time. Here, both are treated identically.
- Current grade point average (GPA) – students are graded on a 4.0 scale, from A to E (fail; no E+). Students who withdraw from a course are given a "W" which does not affect GPA.
- If currently academically dismissed – a student is academically dismissed if their GPA falls below a variable threshold (between 1.00 and 1.95) defined by their completed credit hours, or if their GPA remains below a 1.99 (below a C average) for three consecutive semesters. If dismissed, a student cannot attend CMICH for at least one year and must apply for and receive rematriculation to do so.
- If no longer attending the university – if not academically dismissed nor registered for the current semester.

Surveys were also given in EGR120 from semesters 0809F to 1011S. In every semester, Initial surveys were given at the beginning of the semesters that asked students to rank their top three intended majors ("1" for top choice, "2" for second, "3" for third). In 0809F and 1011F, Final surveys were given at the end of the semester asking questions including

- Previous intended major
- Ranking of new top three intended majors
- Why the intended major changed (if applicable).

4. Enrollment Demographics

4.1 Consistent Distributions

Enrollment in EGR120 is growing at an average rate of 12.4 students per year, mostly in the fall semester: +11.7 per fall (root mean square error (RMSE) = 2.2), +0.7 per spring (RMSE=2.9). The fall semesters are consistently larger (enrollments of 79-143 versus 26-38 for the spring semesters), with an overall enrollment for this study of 828 students. Overall, 78% of the students are in their first year at CMICH (see Fig. 1).

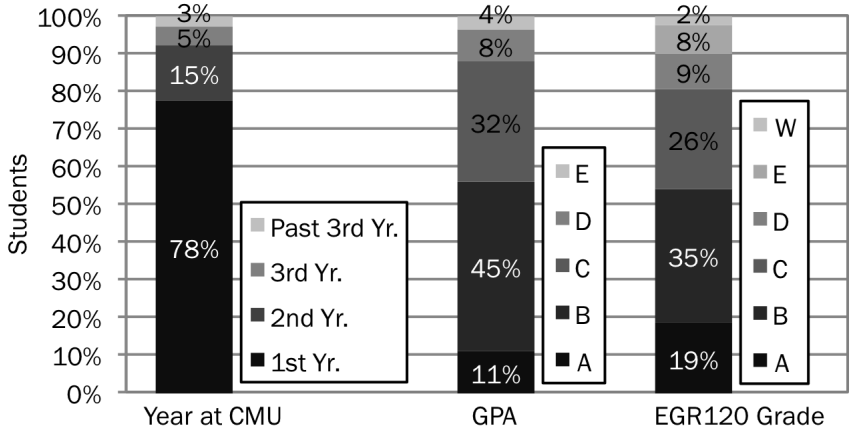

Fig. 1. Miscellaneous enrollment distributions.

The GPAs and EGR120-grades of the students have stayed relatively constant. The GPAs average 2.52 (Fig. 1; standard deviation (STD) across semesters = 0.13). The grades given in EGR120 average 2.48 (Fig. 1; STD=0.19), with the distribution remaining similar.

Surveys of the students show that they are consistently interested in ME followed by EE (Fig. 2). Half the students plan on ME, a quarter plan on EE, and a quarter plan on doing something else. When the rank 1's, 2's and 3's are weighted with values of 3-2-1, as

$$Score = \sum (4 - rank) \tag{1}$$

then the interest is more varied (Fig. 2 far right column) although ME and EE are still the strongest. In the figure, category "(Other EGR)" is student-added engineering disciplines other than ME/EE.

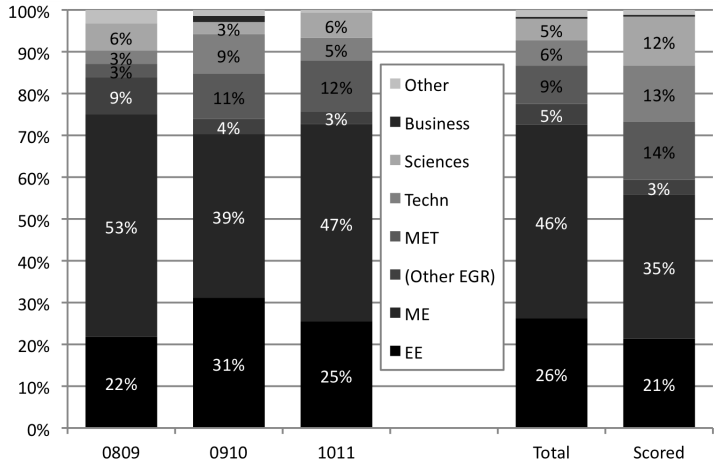

Fig. 2. Interests in various majors, from Initial Surveys. The columns show top choices only (vertical axis is percentage of respondents), except for the Scored column that incorporates first, second, and third choices (vertical axis is percentage of total score).

4.2 Math Level

The MathLevel distributions show the most fluctuations (Fig. 3). The academic plan for engineering students recommends that students take Calculus before or during their EGR120 semester; students with MathLevels of Calculus or Post-Calculus are deemed "OnTrack", while other are deemed "Behind". Only 48% of the students are OnTrack, and only 15% are ahead in math. Furthermore, students taking Precalculus are able to catch up to the academic plan, but students at a lower math level (17%) will need to delay their sophomore-level engineering courses for at least a year to fulfill prerequisites. These numbers are less than encouraging, but not unknown in the engineering literature – for example, the math distribution is remarkably similar to that reported by Richardson and Dantzler[20] (Alabama).

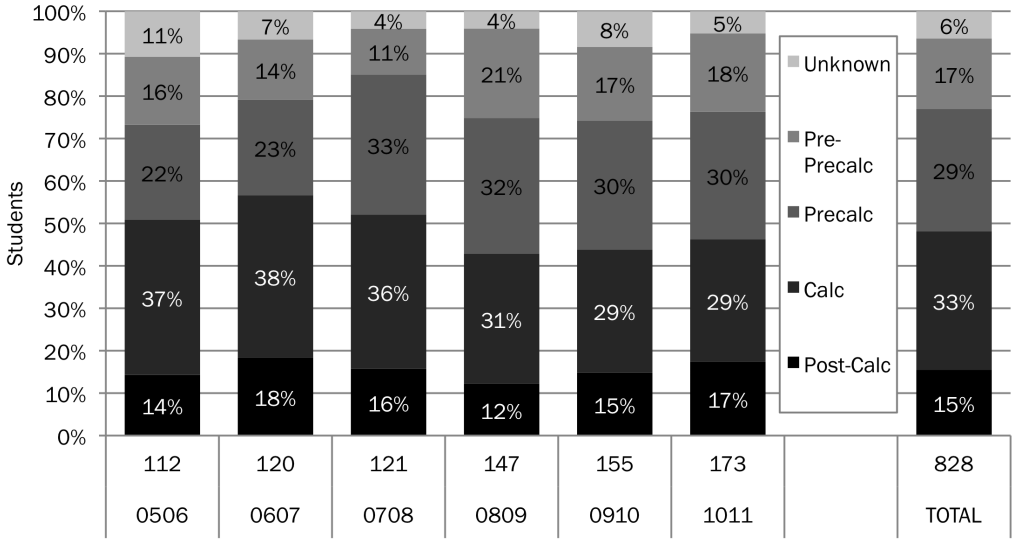

Fig. 3. Math level of enrolled students. On this and similar plots, the number above each horizontal-axis label is the number of students in that year (*e.g.*, 0506 had 112 students).

The math distribution is unfortunately trending towards Behind. Per year, the number of students at each level is growing, but the distribution is shifting towards Behind at a rate of 1.4% per year (RSME=2.7). For example, the number of students per year that are in Calculus is increasing at +1.2/year; however the percentage of students per year that are in Calculus is decreasing at -2.1%/year. Fig. 4 shows the trends of each MathLevel.

Stated differently, each year the enrollment grows by roughly 12 students: 2 ahead, 1 in Calculus, but 9 Behind (5.5 Precalc, 3.5 Pre-Precalc). This trend is problematic. For example, to double the number of On-Track students in the course (from 80 to 160 students), the enrollment would need triple (from 173 to 489 students per year).

Lesson 1: Currently, half of EGR120 students are not prepared to take Calculus. The percentage has been increasing and will most likely continue increasing under the current system.

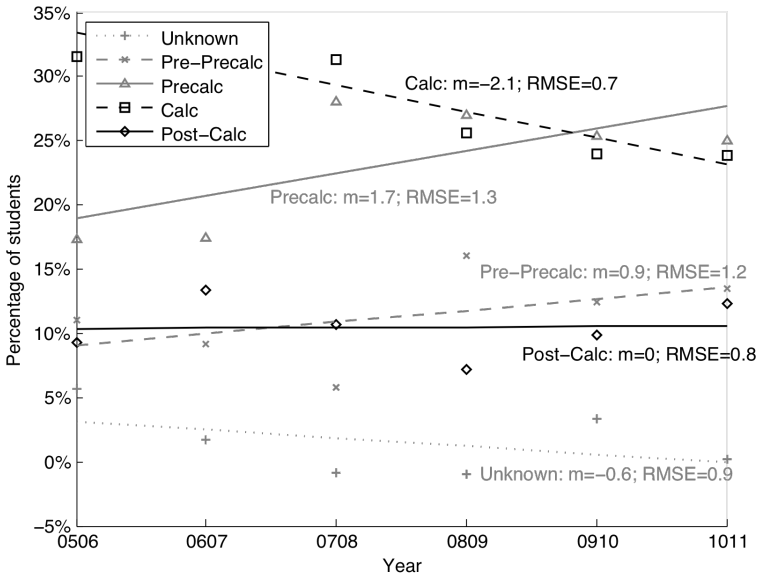

Fig. 4. Trends in MathLevels, as percentage of students.

5. Persistence Demographics

Previous EGR120 students are categorized in the following groups, filled downward:

- Persisted = enrolled in Statics or Circuits
- ETDept = attritted; signed other SET major
- OtherDept = attritted; signed other department's major
- AcadDism = attritted; undecided major; currently academically dismissed
- NotAttend = attritted; undecided major; not currently attending CMICH (but eligible)
- Unknown = attritted; undecided major; attending CMICH.

The Unknown category takes 2-3 years to resolve, as students often take other courses before signing majors. Some Unknowns become Persisted once they complete the required prerequisites and enroll in Statics or Circuits. Other Unknowns eventually sign other majors, get

academically dismissed, or leave CMICH. Because of the delay, *the two most recent years are ignored* in remaining total and average calculations.

5.1 Majors

Overall, 27% of the students persist; 9% go into other SET majors, 30% go into other departments' majors, 13% are academically dismissed, and 19% stop attending CMICH (Fig. 5). CMICH retains 68% of EGR120 students; CMICH retained 77% of all freshmen over the same period.

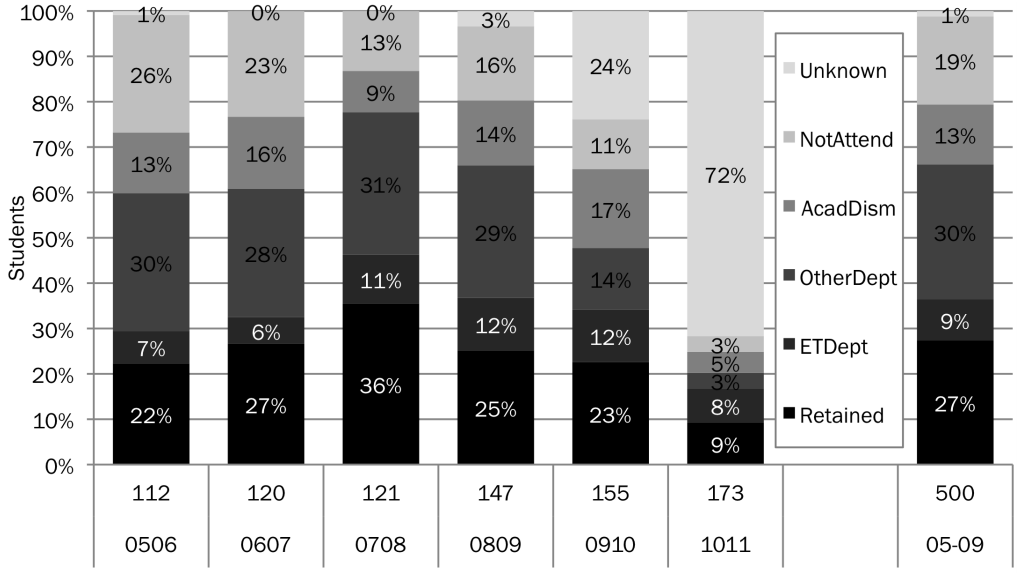

Fig. 5. Persistence of EGR120 students. The far right column ignores the last two years because of the large Unknown percentages.

Of the students still attending CMICH, 41% persist in the engineering programs. This number is more encouraging, but still means that over half of the EGR120 students who stay at CMICH do not stay in engineering. Furthermore, only 13% of those still at CMICH go into other SET majors – historically, EGR120 has not been a great recruiting tool for the other programs in the school. Fig. 6 shows which majors the students are signing.

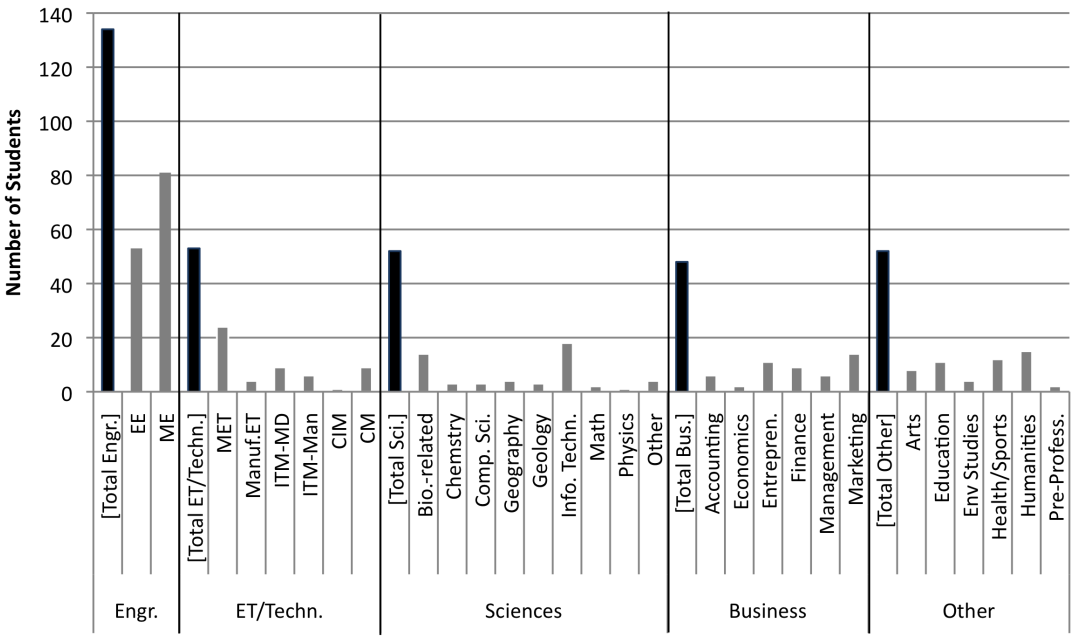

Fig. 6. Current majors of EGR120 students.

Final surveys from 0809F and 1011F indicate that some of the switching of majors occurs during the EGR120 semester. Fig. 7 shows the majors that the students intend on pursuing, from Initial and Final surveys for two semesters. The results show that ME interest dropped significantly, however MET interest grew more sharply in the 1011F semester. This is probably due to the change in teaching method – in 1011F, a technology professor taught a section of the course. Note that the relative interest in sciences and business here does not match the actual resulting majors shown before; more students leave EGR120 planning to major in engineering than actually take the second-year courses.

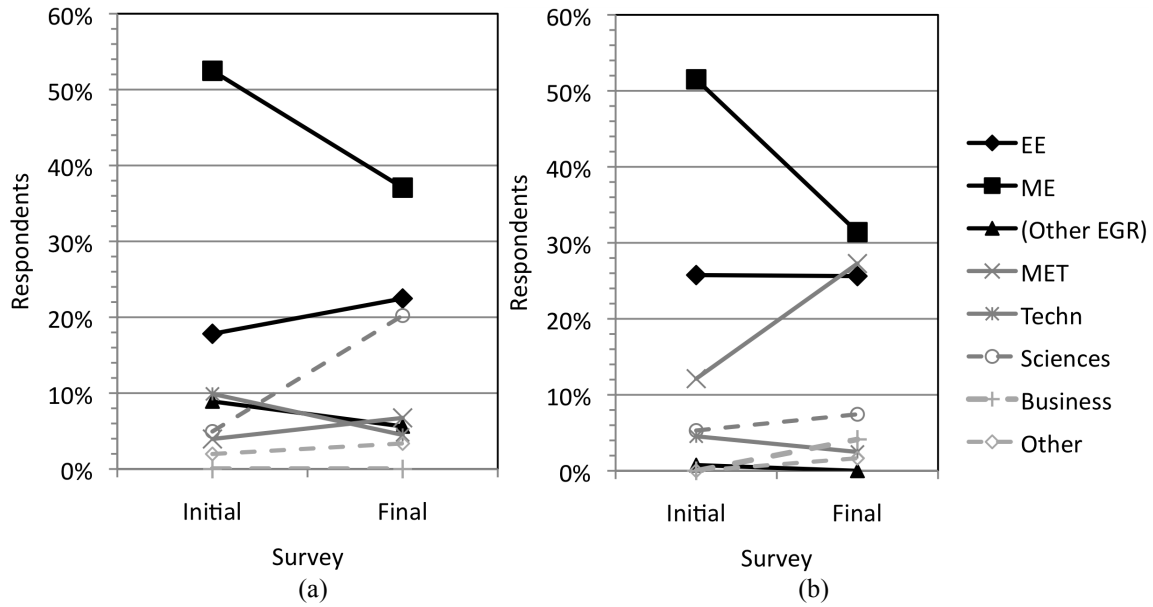

Fig. 7. Comparison of intended majors between Initial and Final surveys, in (a) 0809F, (b) 1011F.

5.2 Math Levels

Persistence is strongly correlated with MathLevel. About two-thirds of the students who are in Calculus II or higher (Post-Calc) persist; only 10% of those in trigonometry or algebra (Pre-Precalc) do. The raw numbers are even more striking: in twelve semesters, only 7 Pre-Precalc and 1 Unknown students have persisted (Fig. 8). It is difficult to compare these Pre-Precalc persistence rates to those at other institutions, as an exhaustive literature search has revealed no data. Of those who do persist, approximately a third were Post-Calc (34%), a third were Calc (34%), and a quarter were Precalc (26%). Of those who persist, there is no significant trend between Behind (31%) versus OnTrack (68%), even though, as shown before, the enrollment is shifting towards Behind. That is, while the EGR120 cohort is becoming more Behind, the subsequent ME/EE-major cohort is not.

Lesson 2: EGR120 has very poor persistence rate of students not yet in Calculus, but good persistence rate of those in Calculus or higher.

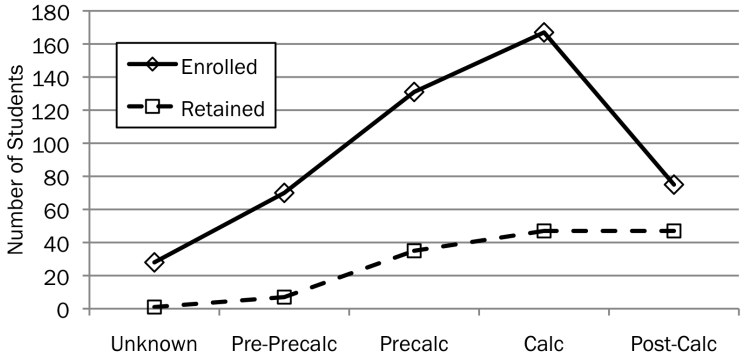

Fig. 8. MathLevel persistence: number of students enrolled and persisting at each MathLevel.

One of the current discussions in the School is the benefits and effects of adding a Precalculus co-requisite to EGR120. EGR120 serves multiple purposes, most notably providing visibility and an introduction to engineering and related fields. The concern is that a co-requisite will reduce enrollment which will (a) reduce the School's funding (since CMICH's budget is based on credit hours), (b) reduce the number of students exposed to engineering and thus decrease majors, and (c) create a math bottleneck similar to the effect of a calculus co-requisite as documented by Ohland *et al.*[21] (Clemson). In these regards, the results are encouraging. While a Precalculus co-requisite will indeed reduce EGR120 enrollment, the data predict at most a 18% drop, assuming students do not enroll in Precalculus *because* of the co-requisite, nor wait a semester or two to take EGR120 once they can satisfy the co-requisite. Furthermore, because very few of the Pre-Precalc students *do* persist, the data predict a drop of engineering majors of no more than 5% (again assuming students do not modify their math enrollment or delay taking EGR120). Finally, the data do not predict a bottleneck, as students unprepared to enroll in Precalculus (as opposed to Calculus) are truly underprepared for engineering and do not, based on the findings in this study, perform well in freshman or later engineering. For that matter, one could view a Precalculus co-requisite as a *de facto* entrance requirement into the engineering programs, or as an earlier and more gracious filter for students who, as found here, have less than a 10% chance of persisting in engineering. A Precalculus co-requisite will also allow for better

use of resources and more advanced discourse in EGR120, possibly improving retention of the math-prepared students.

Lesson 3: A Precalculus co-requisite for EGR120 will reduce EGR120 enrollment by at most 18%, but will only reduce number of engineering majors by 5% or less.

A further option would be to establish a separate introductory course, *e.g.*, Introduction to Engineering Technology, without a Precalculus co-requisite. Such a course would allow CMICH to better serve its existing student population (and thus its institutional mission), allow underprepared-for-engineering students opportunities in engineering-related fields, and even serve as a remedial course for future (but not yet prepared) engineering students, as shown to be successful elsewhere.[22]

5.3 Grades

MathLevel is a good indicator of EGR120 grade (Fig. 9a). Average grade for a Post-Calc student is 3.22 (B+), while average grade for a Pre-Precalc student is 1.67 (C-).

Furthermore, the grade earned in EGR120 is a strong indicator of persistence ($p \leq 0.0001$). For example, 75% of the students who receive an A in EGR120 persist, but only 25% of those who receive a C persist (Fig. 9b). Not surprisingly, EGR120 grade is also a good indicator of Statics grade (Fig. 9c; $m=0.77$, $p \leq 0.0001$) and Circuits grade (Fig. 9d, $m=0.9932$, $p \leq 0.0001$). The Statics and Circuits grades are also highly correlated ($p \leq 0.0001$).

6. Conclusions and Future Work

As always, there is a tradeoff between quantity and quality of engineering students. In the first few years of the engineering programs, CMICH has attracted a decent-sized student cohort to EGR120. The enrollment is still increasing, and will likely continue increasing under the current paradigm.

However, a large portion of the EGR120 cohort is inadequately suited for the mathematical side of engineering. Only half of the EGR120 students are in calculus or higher, and the percentage is decreasing. The cohort growth is mostly of students underprepared for the higher-level math and physics. Growth under the current model is unsustainable, as more and more resources will need to be devoted to the introductory course with little benefit to the subsequent cohort of engineering majors.

Overall, 27% of the EGR120 students persist in engineering. This is low compared to the literature, which shows persistence rates from 30%[17] to 91%[15]. The low persistence rate is partly due to so many EGR120 students being underprepared in math. Students unprepared to take Calculus have extremely low persistence rates – in fact, until now, the progression of Pre-Precalc students is entirely undocumented in the engineering education literature.

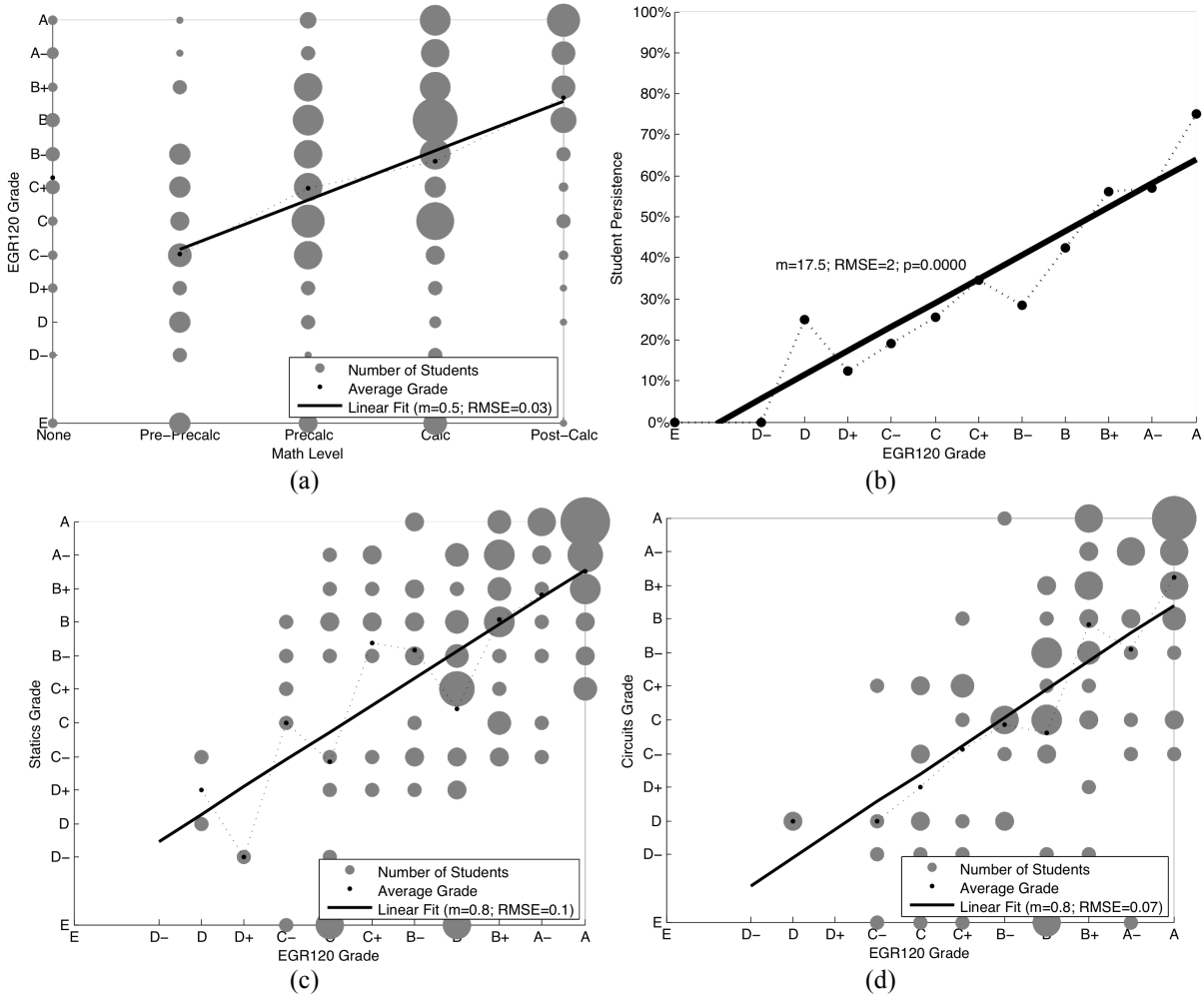

Fig. 9. EGR120 grade (a) versus MathLevel, where marker area corresponds to number of students; (b) as a significant predictor of persistence; (c) as a significant predictor of Statics grade, and (d) as a significant predictor of Circuits grade.

One way to improve the quality of the program and students would be to add a precalculus co-requisite to EGR120. Doing so will reduce EGR120 enrollment, but the number of engineering majors should be much less affected. The precalculus co-requisite should not create a bottleneck (as seen elsewhere with a calculus co-requisite[21]) because the pre-precalculus students, based on the findings in this study, do not persist in engineering. A further option would be to establish a separate introductory course without a precalculus co-requisite to better serve the student population, expose underprepared students to other, engineering-related, fields, and even serve as a remedial course for not-yet-prepared engineering students.[22]

The future focus for CMICH's engineering programs should be on attracting mathematically strong students to the introductory course, rather than on retaining more of the already-enrolled freshman students. EGR120 students in Calculus or higher already have a decent persistence rate. Attracting better-qualified students has more potential than trying to reduce the attrition of those already enrolled.

Another step to improve quality that the School has already implemented is admission requirements. Students are now required to meet GPA and course-specific grade requirements in order to sign engineering majors. This will further reduce the persistence of EGR120 students, but presumably affects students underprepared in math more than those in Calculus or higher. The exact outcome of these strategies remains to be seen.

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