ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #36556

Engineering retention, first-year mathematics performance, and financial aid requirements: A scoping review

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Purpose of Scoping Review

While factors impacting retention in undergraduate engineering are manifold and complex, students' performance in first-year math courses has been identified as a significant predictor of their likelihood of graduating from engineering school [1]–[3]. Scholars have suggested that first-year "barrier" courses in engineering/STEM such as calculus are a turning point for students, who base their decision to continue with engineering studies at least partly on their performance in these courses [1], [4]–[6]. Preliminary research by our research team at the University of Louisville indicated that students who receive a C grade in their first mathematics course have an approximately equal likelihood of (a) completing their 2-year sequence of engineering mathematical requirements, or (b) leaving engineering, by their third year in engineering school [7].

One of the potential reasons that approximately half of these calculus C-grade students may be leaving engineering might be the intersectional consequence with retaining financial aid eligibility. Anecdotal evidence at our university supports this idea; first-year engineering mathematics faculty have regularly heard students report that they were considering leaving (or had decided to leave) engineering because their math performance could negatively impact their GPA, thereby threatening their eligibility for financial aid.

Financial aid is often awarded to undergraduate students in the form of gift aid (money that does not have to be paid back), or self-help aid (loans that do have to be paid back, and/or work-study). Gift aid can be further divided into grants, typically awarded on the basis of financial need, and scholarships, typically awarded on the basis of merit [8]. Common sources of financial aid include the federal government (e.g., the need-based Pell grant, federal student loans) and state governments, many of which offer grants and scholarships. Eligibility for financial aid is often contingent not only on need, but on performance: to continue receiving federal need-based aid, students must demonstrate satisfactory academic progress (SAP) [9], which often includes maintaining a GPA of 2.0, roughly a C average. Merit aid programs, which were adopted by many states in the 1990s to encourage in-state college attendance and improve academic performance, often have even higher GPA thresholds [10]; at the University of Louisville, students must typically maintain a 3.0 at minimum to remain eligible for state-based and institution-based scholarships. However, many students receive a C or lower in their introductory math course, as well as other required courses in the first and second semester of engineering school. The average engineering freshman first-year GPA at our institution is typically between 2.5 – 2.7. Because of financial aid eligibility requirements, these mid-level, passing grades can have substantial negative financial consequences for students. This pattern of achieving a C in first-year calculus and deciding to leave engineering may in fact be a financial aid eligibility issue rather than a straightforward performance issue.

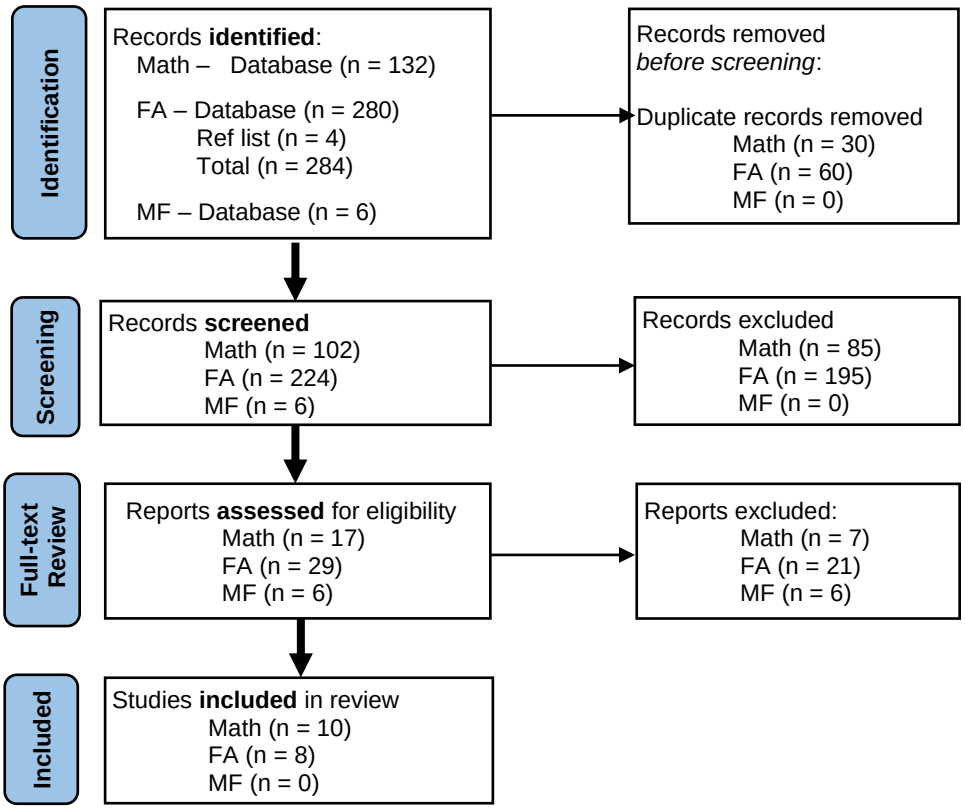
Despite practical implications and anecdotal evidence, there appears to be limited research on the intersection between retention, math performance and financial aid. We decided to conduct a scoping review in order to investigate the viability of an argument that in addition to math

performance itself being a predictor of retention, it may be that there is a substantial interaction effect of math performance with financial aid eligibility that is driving retention down. Our review was guided by the following research questions: 1) What is known about first-year math performance as a predictor of undergraduate engineering retention? 2) What is known about financial aid (particularly financial aid dependence on GPA) as a predictor of retention? And finally, 3) What is known about the intersection of math performance and financial aid (especially dependence on GPA) as predictors of retention?

Methods

Our scoping review followed the guidelines set forth by Arksey and O'Malley [11]. The first step was to iteratively develop search terms that would capture papers of interest and exclude papers that did not relate to the core focus of the search. The second step was to review the abstracts to verify the papers' relevance to our research question. The third step was to read the full texts of relevant papers and synthesize their implications. A diagram depicting our search and review process can be seen in Figure 1.

Figure 1. *Diagram of search and review process*



Note: FA = financial aid, MF = math and financial aid combined, ref list = sourced from reference lists of papers found in database searches.

Positionality

The scoping review team was comprised of the four authors, including the Chair of the Engineering Fundamentals department who has taught calculus to first-year engineering students for over 15 years, a faculty member of the Engineering Fundamentals department with a background in engineering and cognitive science, a Science Education faculty member and Director of the Center for Research in Math and Science Teacher Development, and a graduate student of counseling psychology. Collectively, the author team have studied first-year retention of engineering students for a decade and have published over two dozen articles on this topic.

Search Boundaries

To conduct the search, the databases EBSCO Academic Search Complete, ERIC, and APA PsycINFO were chosen based on their subject matter relevance and/or breadth. The search was limited such that relevant keywords had to appear in the publication's abstract. The search was limited to publications from the year 2000 onward out of concern for older publications no longer being applicable due to changes in higher education (e.g., changes to first-year engineering education, characteristics of students, financial aid policy). Publications were limited to journal articles, conference proceedings, and dissertations. Publications were also limited to English-language only, as the search team lacked the resources to access other languages.

Search Terms

The search team identified key terms of interest (e.g. retention, calculus, engineering, financial aid, performance) as well as related terms (e.g. persistence, success; GPA, grade). Search team members independently and as a team tested various combinations of these terms as part of an iterative process to determine which keywords brought in relevant papers. While some additional terms (beyond those reported below) had initially been included in the hopes of casting a broad net, they were found to capture an overwhelming number of unrelated publications; as a result, these were excluded from the final search implementation.

After the iterative process described above to identify a parsimonious yet wide-reaching set of search terms, in order to capture all three dimensions of the proposed search as outlined in the research questions, two broad searches were first conducted: one examining calculus performance in relation to retention, and another examining financial aid as a factor relating to retention. Then, a final search was done that combined the terms from the first two searches. See Table 1 for the finalized search term combinations that were used for the three searches.

Table 1. *Final search terms for scoping review*

***Search 1, Math and Retention*:** (Engineering)…
AND (Undergrad* *OR* college *OR* university *OR* post-secondary *OR* postsecondary *OR* higher education *OR* tertiary)
AND (Retention *OR* Retain *OR* Persist* *OR* non-persist* *OR* Graduat* *OR* Success *OR* dropout *OR* dropping out *OR* dropped out *OR* withdraw* *OR* leav* *OR* left *OR* stay*)
AND (precalculus *OR* calculus *OR* pre-calculus)
AND (Performance *OR* Grade* *OR* GPA *OR* Achievement *OR* Score* *OR* Exam)
***Search 2, Financial Aid and Retention*:** (Engineering)…
AND (Undergrad* *OR* college *OR* university *OR* post-secondary *OR* postsecondary *OR* higher education *OR* tertiary)

AND (Retention *OR* Retain *OR* Persist* *OR* non-persist* *OR* Graduat* *OR* Success *OR* dropout *OR* dropping out *OR* dropped out *OR* withdraw* *OR* leav* *OR* left *OR* stay*) **AND** (Scholarship *OR* "financial aid" *OR* Satisfactory academic progress *OR* Need-based aid *OR* need based aid *OR* Merit-based aid *OR* merit based aid *OR* grant *OR* Pell *OR* Pell-eligible)
***Search 3, Math, Financial Aid, and Retention*:**
The final search combined those terms used for Search 1 and Search 2 with an '**AND**.'

For a full list of the search terms used during the iterative process, including the terms excluded, interested individuals are welcome to contact the corresponding author.

Initial Abstract Screening

The publications were divided by topic, with one author taking initial responsibility for reviewing publications on financial aid (Search 2), and another taking initial responsibility for publications related to calculus performance as well as publications on financial aid and calculus performance combined (Searches 1 and 3). The authors first conducted a review of abstracts, retaining those that appeared relevant enough to warrant a deeper look. Abstracts were deemed relevant if they reflected one of the research questions. Many papers had some of the keywords, but did not combine them in ways relevant to our research questions. For example, from Search 1, excluded papers fell broadly into categories related to calculus or precalculus course design, bridge program development, or predicting first year GPA and retention based on admission criteria. In addition, duplicates were removed during this initial screening. From Search 2, reasons for exclusion included publications focusing on a construct related to financial aid (i.e., socioeconomic status, tuition) but not financial aid itself; studies taking place outside the U.S., which limited their applicability to the U.S. higher education context; and studies evaluating engineering scholarship programs, which did not explore financial aid specifically in relation to retention. Search 3 turned up no relevant publications (see Figure 1).

Full Text Processing

The full texts of all relevant-likely publications were acquired and reviewed both for confirming relevance and to extract information. Across all publications, the following information was extracted from each: type of study (quantitative or qualitative, cross-sectional or longitudinal), region or state where the study took place, timeframe of data collection, and notable outcomes (specifically, what was found regarding the relationship between calculus performance/financial aid and retention). For the searches focusing on calculus performance and financial aid, additional features were identified to be meaningful while conducting the full-text review. These additional features, along with information that was universally extracted from publications, are listed in Tables 1 and 2.

Results

The results of our scoping review are organized broadly by our three a priori research questions: 1) the relationship between math performance and retention; 2) the relationship between financial aid and retention; and 3) the combined effect of math performance and financial aid on retention. Within each section, themes and key takeaways are highlighted.

Table 2. *Math Performance and Retention Studies*

Reference	Sample	Year of cohorts	Design	Math courses included	Retention definition	Retention outcomes	Analyses
Baisley et al., 2019 [12]	Western university (*n*=3,927)	2005-2018	longitudinal	Calculus I	Graduated or enrolled after Calc I	Calc I grade most significant predictor of persistence or graduation; for every increase in letter grade, likelihood of graduation increased 2.1 times	Logistic modelling
Bowen et al., 2019 [4]	Midwestern university (*n*=1,576)	2005-2011	longitudinal	Calc I eligible/ineligible; at-risk status	Six-year graduation	Calc eligible and not-at-risk are 14 times as likely to graduate than those at-risk and not Calc eligible	Logistic modelling
Dwyer et al., 2020 [13]	US Air Force Academy (*n*=4,498)	2015-2019	longitudinal	Calc I, Chem I, Physics I	graduated	Calc I top predictor of graduating with STEM degree; students with better grades 98.1% more likely to graduate	Logistic modelling
Inkelas et al., 2021 [14]	Mid-Atlantic university (*n*=2,689)	2009-2016	longitudinal	Calc I and Calc II (on-track calculus)	graduation	Students beginning in Calc I had lower GPA ($p \leq .001$), and longer time-to-degree ($p \leq .05$) than those in Calc II.	Sequential, exploratory, mixed-methods design; t-tests, hierarchical multiple regression
Krause et al., 2015 [1]	University in southwest (*n*=615)	2007	longitudinal	Below Calc, Calc I, and above Calc I	2nd year, and six year graduation	Students making A/B grades in first math course were 6.5 times more likely to persist than those making C/D/F/W	Logistic modelling
Lougheed, 2015 [15]	Western university (*n*=3,777)	2001-2005	longitudinal	Calc I, Calc II or Precalculus	STEM degree within 6 years	Grade in first math course (calc or precalc) is most important predictor of STEM graduation – range of graduation rates between highest (A) and lowest (F) grades is up to 65%	Logistic modelling
Suresh, 2003 [16]	University in northeast (*n*=750)	1997-1999	longitudinal	Barrier courses (BC): Calc I & II; Phys I & II	Year two	Model did not explain connection between performance in BC and persistence	Chi square tests of independence; regression analysis
Tyson, W. 2011 [17]	Florida Univ. (*n*=1027)	2002-2003	longitudinal	Calc I, II, & III; Physics I & II	graduated	No uniform effect of math performance on graduation	Multinomial logistic modelling
Van Dyken et al., 2015 [6]	Southern univ.; study 1 (*n*=4,040) study 2 (*n*=814)	2009-2012	longitudinal	Precalc, Long Calc, Calc I, II, or III	One year (study 1); graduated (study 2)	Grade and course significant predictors of retention and graduation (multiple odds reported)	Logistic modelling; percentages graduated
Wilkins et al., 2021 [18]	Midwestern public univ. (*n*=1,504)	2005-2009	longitudinal	First semester math course; Calc I,II, Trig; Precal	Six-year graduation	Students who did well (A grade) in Precal (probability of 0.69) or Trig (0.74) were as likely to graduate as those who made B or C in Calc I (0.74 and 0.62).	logistic modelling

Math Performance and Retention

The scoping review identified 102 papers on math performance and retention after duplicates were removed. Of those, all but 17 were excluded based on the initial abstract screening. After a full text review, an additional 7 papers were also categorized as irrelevant to our research questions (see Figure 1). After the full-text review, a total of 10 papers were retained, with key features of these studies summarized in Table 2.

All ten studies were longitudinal in that they related performance in the first math class (most often Calculus I) to retention and persistence, in some cases to both first-year retention and to graduation. Eight of the ten studies utilized binomial logistic regression for prediction of retention or graduation rate. Not unsurprisingly, students who take Calculus I (or a more advanced Calculus course) as their first mathematics course and who are more successful in their first mathematics course are more likely to graduate with a degree in engineering [6], [18] or STEM more generally [15].

Math placement as a significant predictor of retention

To varying degrees, six of the papers discussed math placement [1],[4],[6],[9] – [11] in relation to math performance. Some focused on the importance of Calculus I or higher. For instance, Bowen et al. [4] considered calculus eligibility and at-risk status at the end freshman year (defined as GPA <3.0). Their study documented the importance of taking Calculus I or higher and maintaining a 3.0 during their first year. They found that considered together, the odds for students to graduate in engineering who were calculus eligible and not at-risk at the end of their first year were 14 times that of students not calculus eligible and at-risk at the end of the first year. Another study [14] differed from all the others in that Calculus I was considered a prerequisite course at a highly selective institution. Their results suggested that starting in Calculus I instead of Calculus II was negatively associated with graduating GPA, time to degree, and likelihood of majoring in popular engineering disciplines [14]. Krause et al. [1] found that students placing below Calculus I left engineering in higher numbers than those taking Calculus I or higher. Specifically, they found that students taking a math course above Calculus I were 2.3 times more likely to persist to graduation than students taking Calculus I, and that students taking Precalculus had 40% of the odds of someone taking Calculus I. In their study, students starting below Calculus I had a 30% chance of graduating, but students who started in Calculus I or higher had between 50-70% chance. Van Dyken et al. [6] also found that a minority of engineering graduates started below Calculus I. Lougheed [15] found similar results for STEM majors in that the proportion of STEM graduates rose significantly if the first mathematics course was a higher placement in the Calculus sequence.

However, starting in Calculus I or higher *is not necessarily always the optimal* choice. Wilkens et al. [18] found that when controlling for grade, on average, students whose first math course was Calculus I were more likely to persist to an engineering degree than those who took a mathematics course below Calculus I. Students starting in Calculus II were not more likely to graduate in engineering than those starting in Calculus I, and those starting in more advance courses were only marginally so. Further, when they explored specific course and grade combinations with their model, they found that students making an A or B in precalculus or

trigonometry were as likely to graduate in engineering as students making a B or C in Calculus I. Importantly, they found that students who earn an A in Precalculus are more likely to graduate in engineering than students who earn a C in Calculus I. This study impels faculty and advisors to work to properly place students in their first mathematics course.

Math performance as a significant predictor of retention

A number of studies demonstrated that a student's grade in the first mathematics course, even if below Calculus I, was of prime importance for strengthening retention. Nine of the ten papers from the review of mathematics performance confirmed that mathematics performance is a significant predictor of retention and persistence to graduation in STEM. Lougheed [15] found that performance in the first math course was the most significant factor in predicting STEM graduation, whether it was Calculus or Precalculus. Results showed that as the grade went up, or the first course was a higher placement in the Calculus sequence, the proportion of STEM graduates rose significantly. Of concern, and of interest to us, was that less than 34% of students with grades in the C or C+ range persisted to graduate in STEM. Wilkins et al.'s [18] model demonstrated that when controlling for students' first mathematics course, on average, the grade in their first course is a statistically significant predictor of persistence to graduation in engineering. Krause et al. [1] also found that students who made an A or B in their first mathematics course had odds 6.5 times higher to persist than someone who received a D, F or W. Further, students receiving C grades in their first course did not differ statistically in terms of persistence from those making a D, F or W.

Tyson [17] considered high school and college physics and calculus course-taking and achievement to predict engineering degree attainment for students on track for an engineering degree at four-year institutions in Florida by examining graduates. Thus, this study compared students who successfully graduated with an engineering degree to students who successfully earned non-engineering degrees. The study hypothesis was that students who earned higher grades in college physics and calculus would have lower rates of switching out of engineering compared to lower achieving students. However, in contrast to other studies, no uniform effect of mathematics course performance on degree attainment was found. The likely explanation for this difference is that the study sample required students to have taken one or more engineering courses to be included. Most of these students would have made it past the early period of attrition due to low grades in barrier courses.

Of particular interest were two studies that compared persisting students to leaving students. Baisley and Adams [12] looked specifically at Calculus I and found that persisting students averaged a B grade in Calculus I, while non-persisters averaged a C+. Interestingly, of students with low grades who retook the class, 48% of them were successful and persisted in engineering. Another extensive study [16] found that "struggling persisters," students who made low grades or repeated Calculus I, were not significantly different from "non-persisters" in terms of high school GPA or entrance scores. Qualitative analysis revealed that what differentiated them was commitment and motivation to become an engineer. These studies provide inspiration for intervening with students who make C grades in Calculus I.

Table 3. *Financial Aid and Retention Studies*

Reference	Sample (*n*, state or region)	Year of cohorts	Design	Type of aid	Retention outcomes	Analyses
Bengesai and Paideya, 2018 [19]	South Africa (*n*=1,595)	2009-2011	Quantitative, longitudinal	Unspecified	Financial aid increased likelihood of graduation (within 4-8 years) by up to 55%	Logistic regression, multinomial regression
Castleman, Long, and Mabel, 2017 [20]	Florida; Pell-eligible students (*n*=2,934; 1,283)	2000-2001	Quantitative, longitudinal	Need-based state scholarship	Need-based aid increased 8-year graduation by 3%, STEM credits taken by 16-35%	Regression discontinuity
Cornwell, Lee, and Mustard, 2006 [21]	Georgia; received HOPE scholarship (*n*=31,118)	1990-1995	Quantitative, longitudinal	Merit-based state scholarship	Merit-based aid linked to 65% increase in STEM credit withdrawal and 6% decrease in completed STEM credits	Multinomial logistic regression
Fenske et al., 2000 [22]	U.S., large public urban university (*n*=1,967; 1,679; 1,614; 1924)	1989-1992	Quantitative, longitudinal	Both gift aid (merit or need-based) and self-help (loans, work-study)	Gift aid-only increased persistence to graduation with STEM degree, loans decreased persistence	Weighted averages, chi-square tests, percentage change
Pocock, 2012 [23]	South Africa; engineering students (*n*=2,319)	2004-2009	Mixed methods, longitudinal & cross-sectional	Unspecified	In 48% of students who left engineering, lack of financial aid led to attrition	Calculation of loss rates
Roberts, 2016 [24]	U.S., Pell-eligible engineering students (*n*=16)	n/a	Qualitative, cross-sectional	Both gift aid (merit or need-based) and self-help (loans, work-study)	GPA requirements motivate student persistence and success	Interpretive phenomenology
Sjoquist and Winters, 2015 [25]	U.S.; College graduates across 27 states (*n*=418,739)	2009-2011	Quantitative, longitudinal	Merit-based state scholarship	Adoption of strong merit-based aid program decreased STEM graduation by 6.5%	Difference-in-differences regression
Tyson, 2012 [26]	Florida, 4 universities; (*n*=73) (also interviewed faculty, staff, & administrators)	n/a	Qualitative, cross-sectional	Unspecified	GPA requirements deterrent to persistence	Thematic analysis of interview and focus group data

Financial Aid and Retention

The scoping review identified a total of 224 unique publications pertaining to financial aid and retention. After abstract review, 31 full-text publications were retained. After a full-text review, another 23 records were excluded due to irrelevance to the research questions. A total of eight papers were retained; details of these publications are available in Table 3.

Two broad themes emerged that have been used to organize the findings of this section. The first theme centered around the question of whether financial aid predicts persistence. While consistent evidence was found for financial aid's role as a predictor, studies varied on whether the relationship was positive or negative. The second theme focused on the roles of different types of financial aid, and (relatedly) GPA requirements for financial aid, in relationship to persistence in engineering.

Financial aid as predictor of retention

Three publications directly investigated the hypothesis that financial aid was positively predictive of persistence in engineering. Castleman et al. [20] tested whether students who were eligible for both the Pell grant and additional state aid (the Florida Student Assistance Grant, or FSAG) took more credit-bearing STEM courses and/or graduated with STEM majors at a higher rate than students who were Pell-eligible but not eligible for the FSAG. They [20] found that students who received both the FSAG and Pell grant earned 16-35% more STEM credits than their peers who only received the Pell grant (percentage increased for students with higher academic readiness). A weaker (non-significant) relationship was found for completion of STEM degrees, with only a 3% increase in the 8-year graduation rate. Bengesai and Paideya [19] examined multiple predictors of engineering students' graduation rates (within range of 4-8 years depending on cohort) at a South African university, including demographic variables, pre- and during-college academic performance, and institutional factors such as financial aid. Bengesai and Paideya [19] found that students with financial aid were up to 55% more likely than those without to graduate in four years. Pocock [23] conducted a case study examining factors predictive of engineering student attrition at a South African university. Examining a subset of students who left the engineering school in 2008-2009, Pocock [23] found that 48% of these students left due to financial reasons, including lack of financial aid.

Conversely, some studies tested the hypothesis that merit-based financial aid negatively predicted persistence. Comparing STEM degree completion rates in states with "strong" merit programs to states that had no merit program, Sjoquist and Winters [25] found that having a strong merit program consistently reduced the probability of students graduating from college with a STEM degree by approximately 1.3%. Considering that only 1/5 college graduates major in STEM, Sjoquist and Winters [25] suggest that adoption of strong merit programs reduces the number of STEM graduates by 6.5%. Cornwell et al. [21] also examined the effects of a state-sponsored merit-based aid program, Georgia's HOPE program, by comparing students eligible to receive the HOPE scholarship (virtually all in-state students) with a control group of out-of-state students. Cornwell et al. [21] found that amongst HOPE recipients there was a 65% increase in withdrawals from STEM courses relative to out-of-state controls, and a 6% decrease in completion of STEM courses across HOPE recipients' first two years in college. Conversely, no

increased withdrawal was found for HOPE recipients in non-STEM courses. However, HOPE's effect on STEM course-taking did not correspond to a statistically significant decrease in how many HOPE students declared STEM majors.

While studies examining financial aid as a predictor of retention seem to have yielded contradictory findings, these deviations might be explained by the type of financial aid being studied. Castleman et al. [20] examined the need-based Pell grant and FSAG, which ostensibly carried lower GPA eligibility requirements than the merit-based programs that were reviewed. It is unknown whether financial aid awarded to South African engineering students in the two studies reviewed was need-based, merit-based, or a combination. However, Pocock [23] only examined students who were not excluded due to academic reasons, suggesting that financial aid would have had a positive impact on these students' ability to persist in engineering.

Role of aid type and academic requirements

A key factor in the Sjoquist and Winters [25] as well as Cornwell et al. [21] analyses was that they concerned merit-based aid, raising the question of whether the relationship between financial aid and persistence varies as a function of the type of aid provided. Both sets of authors acknowledged that their results could not shed light on the mechanisms behind merit-based programs negatively predicting STEM credits completed. Both sets of authors also suggested the possibility that students who did poorly in STEM courses and feared losing financial aid eligibility (or had already lost and wanted to regain eligibility) would withdraw from STEM courses or switch to non-STEM majors to maintain the GPA required for eligibility. Findings from two qualitative studies bolster this possibility.

Roberts [24] studied the lived experiences of engineering students with high financial need and the strategies they used to persist in engineering. All 16 participants in Roberts' study received the Pell grant and borrowed federal student loans to finance their education. When asked about their motivations for achievement, several students reported that fear of losing financial aid eligibility drove their efforts to maintain or raise their GPA. Need-based federal and state aid are typically conditioned on satisfactory academic progress (SAP), which at most institutions includes maintaining a minimum GPA of 2.0. Reflecting this, in the Roberts study, concerns about GPA requirements were voiced by merit-based aid and need-based aid recipients alike.

While participants in Roberts' study spoke of financial aid GPA requirements as a motivation for persistence, another study reported that GPA requirements could be an impediment to persistence. Tyson [26] conducted interviews with engineering students, faculty, and staff to explore their views on the impact of employment on students' persistence. Students overwhelmingly reported that working outside jobs was necessary for them to continue schooling or maintain their quality of life. Though some faculty and staff stated that students could apply for scholarships or internships, these options were not viable for students who did not meet the GPA requirements. Being ineligible for financial aid contributed to a vicious cycle in which students had to continue working to pay for school, which took time away from studying, contributed to lower grades, and made it more difficult to continue engineering studies.

Only one study compared different types of aid in relation to persistence. Fenske and colleagues [22] examined patterns of financial aid packages awarded to four undergraduate STEM student cohorts from 1989 to 1997 at a large public institution, focusing on the relationship between demographic factors, types of aid, and retention. Fenske found that students who took out loans – whether alone or in combination with gift aid – left STEM in greater numbers than students who only received gift aid. Conversely, students who received only gift aid persisted in higher numbers. However, given the descriptive nature of the study and the fact that merit-based and need-based aid were collapsed into the single category of gift aid, these findings do not shed additional light on whether merit-based aid and need-based aid differ in their impacts on retention.

Math Performance and Financial Aid

In the third search, only 6 papers were returned, none of which [6], [27]–[31] directly addressed the potential interaction between math performance, financial aid, and retention. It is clear from this scoping review that this potential intersection is understudied in engineering retention.

Limitations and Future Directions

First, as with any comprehensive review, there is a possibility that relevant publications were not captured by our searches. While our team made iterative adjustments to our search terms to more effectively target the intersection of math and financial aid with retention, there may be other keywords we did not utilize that could have identified publications of interest. Second, the paucity of research speaking directly to this intersection may itself be considered a limitation of our review. While separate searches for math performance and financial aid provided evidence that both math performance and financial aid are predictors of retention, we could find no quantitative research directly testing the hypothesis that engineering students leave engineering to remain eligible for GPA-dependent financial aid.

Third, the purpose of this scoping review was to provide a broad overview and synthesis of extant literature on mathematics performance, financial aid, and retention in undergraduate engineering. Therefore, conducting assessments of the quality of the studies reviewed fell outside the methodology for this scoping review, which limits our capacity to speak to the dependability of extant research. However, if there were an adequate number of relevant high-quality studies, these topic areas may benefit from a systematic review or meta-analysis in which studies were evaluated for quality of evidence. Within a meta-analysis, examination of potential mediators or moderators of study results could also be conducted.

Conclusions

This paper describes results from a scoping review of existing literature on first-year math performance and financial aid as predictors of undergraduate engineering retention. Overall, it appears that math placement, math performance, having financial aid, and financial aid type are meaningful factors in engineering retention.

Studies on math placement showed that students who take and pass Calculus I or a more advanced course are more likely to graduate with a degree in engineering. However, making a good grade in the first course, whether it was Calculus I or a precalculus course, most closely predicted persistence to graduation in STEM [15]. Making an A or B in precalculus or trigonometry was as predictive of engineering graduation as students making a B or C in Calculus I [18]. Studies comparing those who persist with those who do not [12], [16] provided evidence that more work is to be done to place students in appropriate courses, and to try to retain C grade students who have successfully passed the course.

With respect to financial aid's impact on retention, evidence was split on whether financial aid had a positive or negative effect [19], [20], [23]. Some authors proposed that the type of financial aid may matter [22], with merit-based financial aid potentially having a negative effect [21], [25]. One proposed mechanism for this finding was that poor performance in first-year STEM courses could threaten students' eligibility for financial aid, and that students left STEM courses and majors to preserve their GPAs and eligibility. In two qualitative studies, students voiced this exact conundrum, with some students feeling pressure to improve performance to maintain/regain eligibility and other students being forced to delay graduation or leave their studies due to financial difficulties and ineligibility for financial aid [24], [26].

No publications examined the issue of financial aid eligibility specifically in relation to first-year engineering math, such as calculus or pre-calculus. Given the paucity of research in this area, we think this is a very promising area for further development. When both sets of studies are juxtaposed, it seems plausible that many C-in-Calculus I students may be leaving due to concerns with maintaining financial aid rather than direct concerns about their math performance. We hope to utilize the results of this review to guide future research on the role of financial aid eligibility in the decisions engineering students who earned a C in their first undergraduate mathematics course make concerning when to persist or leave.

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