Calculus Readiness and Retention Rates for Homeschooled Students in a Four Year Engineering Program

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Abstract

Cedarville University has an unusually large population of students who were homeschooled when they graduated from high school (about 1/5 of students university wide and 1/4 of students currently enrolled in the School of Engineering and Computer Science). In this paper, I investigate the retention rate and calculus readiness for homeschooled students entering the School of Engineering and Computer Science as compared with their non-homeschooled peers.

In this study, I hypothesized that homeschooled students might have a different likelihood to succeed in engineering school compared to their non-homeschooled peers. The results of the data study support this hypothesis and suggest that homeschooled students are more likely than others to succeed in engineering school, with retention in (and graduation from) the School of Engineering and Computer Science as the primary metric of success. Data studied include ACT composite and ACT math scores, retention rates, and scores from an internal math placement test administered to all incoming freshmen. The results also begin to narrow down the likely reasons why homeschoolers tend to perform differently than their peers. Higher rates of calculus readiness upon entry into college is considered as a possible explanation for homeschooled students' increased retention. However math preparedness scores are not found to set homeschooled students apart from others. Therefore, even though neither group of students studied is apparently disadvantaged in math preparedness, homeschoolers have higher retention rates and are therefore more likely to graduate in engineering. While the data studied do not offer a cause for this retention difference, I identify in the literature and discuss in the paper the possible explanation of homeschoolers tending to be more indpendent learners and therefore more successful in engineering school.

1 Introduction

1.1 Background and Motivation

Homeschooling has been slowly increasing in popularity in recent decades, now representing the education of about 3% of school age children in the United States [1] and growing at an estimated rate of 2-8% a year [2]. Homeschooling families have also been becoming more diverse in the last 20 years (about 1/3 of homeschoolers are non-white [2]), as have the reasons for choosing a homeschool situation over a traditional public or private school [3]. Educational methods for

homeschoolers are varied, including online schooling, co-ops, traditional textbook usage, literature-based learning, unschooling, part time participation in public school or extracurriculars, dual enrollment at colleges, and classical education approaches. While U.S. regulations vary from state to state, all 50 states currently allow families to choose homeschooling.

Homeschooled students' academic outcomes are typically very good [4]. Homeschoolers, on average, have higher standardized test scores [2], GPA's, and graduation rates in high school. Homeschoolers typically have no additional difficulty with college admission, the vast majority of colleges having formal application procedures to accommodate homeschooled students (83% of colleges in 2004) [5].

While families choose homeschooling for a variety of reasons (academic rigor, individualized educational goals, to teach a particular worldview, special learning needs, to enhance family relationships, low availability of quality schools in certain locations, etc. [2]), technology may be playing a role in the growing number of homeschoolers. Parents in the tech fields, especially entreprenurially minded ones, seem to be becoming more interested in a do-it-yourself approach to their children's education [6]. Online educational resources are more plentiful than ever, and some technologically-minded families are taking advantage of them on their own terms, specifically attempting to encourage their children toward independent thinking, curiosity, and creativity.

In this paper, I would like to explore the question of how homeschoolers fare specifically in undergraduate engineering programs, compared to their non-homeschooled peers. Cedarville University has the unusual situation of attracting a disproportionately high number of homeschooled applicants. In recent years about 1/5 of the university's students have come from a homeschooling background. Current enrollment in the School of Engineering and Computer Science shows that closer to 1/4 of engineering students were homeschooled. This creates an opportunity to compare a significant number of similar students (in that they selected and were accepted to the same engineering program, therefore having met the same academic standards with respect to test scores and high school GPA's), but who differ in type of schooling in high school.

As educators, we are interested in increasing our knowledge about what skills or characteristics indicate an increased likelihood of student success. If homeschooled engineering students have an apparent advantage or disadvantage compared to their classmates, it would be beneficial to be aware of the discrepancy and possible reasons for it. I would also like to know as much as possible about why the discrepancy exists and what skills we educators could emphasize in order to fortify the disadvantaged group and close the gap.

1.2 Cedarville University's School of Engineering and Math Placement Testing

Cedarville University's engineering program began in 1990 and has grown steadily since, now with over 300 students, six majors, and 24 full time faculty members. The programs are accredited by the Accreditation Board for Engineering and Technology (ABET), though at the time of this writing accreditation for two new programs is pending.

The School of Engineering works very hard to advise each new and prospective student toward a

successful academic trajectory, and student preparedness in math is perhaps the most significant and measurable indicator we have to help us toward that goal. The Science and Math Department offers an internal placement test for incoming freshmen called the calculus readiness exam. The test is given to any incoming freshmen who are enrolled in a major for which they will need to take Calculus 1 (science, engineering, math). Based on years of experience, the School advises students who correctly answer 13 or less out of 25 problems to enroll in Pre-Calculus rather than Calculus 1. That is, the math and engineering faculty have determined this assessment to be strongly predictive of student success in required first year math classes, and therefore also in technical majors, though initially underperforming students often graduate successfully if they take extra time in college. A practice/sample version of the placement test is available to the public, and prospective families, online. The results of this test for several years worth of incoming engineering students will be one of the data used in this study to investigate how and whether homeschooled vs. non-homeschooled students tend to fare differently in engineering school.

2 Methodology and Data

The data used for this study were collected from existing student data archives held by the university. It was acquired without reference to student names and under the approval of the Institutional Review Board (IRB). The data were from all students in the last ten years who declared an engineering or computer science major upon enrolling in the university. A total of 1,930 students were represented overall, 426 of whom were homeschooled. Data collected included the following fields:

- Graduation date (if the student graduated from the university)
- Hiatus start date (if the student left the university)
- High school type (homeschool, public, or private)
- Calculus readiness placement test score
- ACT composite and ACT math
- SAT composite and SAT math (the university requires either the SAT or the ACT)
- High school GPA
- College GPA
- Number of credits completed
- New student term (the semester the student started at the university)
- Current major (for current students)
- Major at graduation

“High school type” is understood to be the self-declared category (public, private, homeschool) of the institution granting the high school diploma. Many of the students may have experienced

multiple types of schooling at different times in their lives, but that information is not part of this data set.

Not every field was populated for every student. For example, many students submit only the SAT or ACT, not both; students who transfer introductory math classes do not necessarily take the calculus readiness placement test; not every student has graduated from the university; etc. Therefore, the averages shown in the results should be understood to be the averages for the students with data for the statistic in question. Table 1 lists the number of student scores available for each of the assessments.

Table 1: Number of test scores available in dataset for each category of interest out of 1930 total students represented (n-values)

	Incoming		Graduated	
	Non-homeschooled	Homeschooled	Non-homeschooled	Homeschooled
# calc readiness scores	1133	278	317	98
# ACT scores	1079	263	301	95

The main performance criteria I wished to study were calculus readiness and retention. Calculus readiness is measured primarily by the calculus readiness placement test score and secondarily by the ACT score (since a greater number of students studied took the ACT as opposed to the SAT). I defined retention as graduation from the School of Engineering and Computer Science. That is, if a student graduated from the university but with a major outside the School of Engineering and Computer Science, he is not considered to be retained. Similarly, if a student left the university entirely, he is not retained. However, if a student kept the same major or changed to a different major within the School and graduated from the School, I consider him to be retained.

3 Results

The following results show statistics on calculus readiness metrics and retention rates by year, with students separated into two groups for comparison: homeschooled and non-homeschooled.

3.1 Test Scores: Comparing Homeschoolers to Others

The first comparison to be made is that of test scores for incoming homeschooled vs. non-homeschooled students. Tables 2 and 3 give overall average test scores for the students studied. Table 2 shows the test scores for all students who started in the School of Engineering, while Table 3 shows the test scores but limits the data to the students who finished in the School of Engineering. As one would expect, students who successfully graduated with an engineering degree (Table 3) have higher average scores than students who began but did not necessarily remain in the engineering program (Table 2).

The salient piece of information for this study is the fact that homeschooled and non-homeschooled students have essentially the same math test scores, that is, their average scores show statistically insignificant differences. This can be shown using a one sample

Table 2: Average test scores for all **incoming** School of Engineering students from 2009-2019 with 95% confidence intervals (1411 students, 278 of which were homeschooled)

	Homeschoolers	Non-Homeschoolers
avg calc readiness score	17.137 CI [16.09, 18.19]	17.508 CI [17.24, 17.78]
avg ACT	28.559 CI [26.84, 30.27]	27.503 CI [27.28, 27.72]
avg ACT Math	28.148 CI [26.45, 29.84]	28.202 CI [27.42, 28.98]

Table 3: Average test scores for all students **graduated** from the School of Engineering from 2013-2019 with 95% confidence intervals(415 students, 98 of which were homeschooled)

	Homeschoolers	Non-Homeschoolers
avg calc readiness score	18.163 CI [16.33, 20.00]	19.363 CI [18.40, 20.32]
avg ACT	28.632 CI [25.81, 31.45]	28.485 CI [27.03, 29.94]
avg ACT Math	28.674 CI [25.83, 31.51]	29.449 CI [27.95, 30.95]

hypothesis test where the sample means for the homeschooled and non-homeschooled groups are compared to the population mean (the average test scores of all students in the dataset). Table 4 lists the average test scores of all students in the dataset. For each of the three score categories, the following hypothesis can be formulated: average homeschool test score is equal to average overall test score. The alternative hypothesis is that the average homeschool test score does not equal the average overall test score. With a confidence level of 95% and a two sided test, a z-score of -1.96 can be compared to sample statistic values calculated using the formula

$$s = \frac{\bar{x} - \mu_0}{\sigma/\sqrt{n}},$$

where $\bar{x}$ is the sample mean for the group, μ_0 is the population mean, σ is the population standard deviation, and n is the number of samples in the group. So, for example, in the case of the calculus readiness test scores of incoming engineering students,

$$s = (17.14 - 17.44)/(4.63/\sqrt{278}) = -1.07 > -1.96,$$

therefore the hypothesis is accepted. By similar analysis, in each case (save one) of homeschooled students' test scores (both for incoming and graduated students), the hypothesis is accepted, meaning that there is no statistically significant difference between homeschooled students' math readiness scores and the math readiness scores of other students. The only case in which the hypothesis test fails is the case of the ACT composite score. These data show that incoming homeschooled students have a slightly higher average ACT composite score than non-homeschoolers. However, the same homeschoolers do not have significantly higher average ACT math scores. From this analysis, I conclude that, by these testing metrics, the homeschooled students are, on average, equally prepared in math compared to their non-homeschooled peers.

Figures 1, 2, and 3 show the test score data (ACT composite and calculus readiness test) broken up by year with a depiction of the standard deviation for completeness' sake. The diameter of each circle represents the magnitude of the standard deviation in the test scores for that year. Again, the scores for homeschooled vs. non-homeschooled students are very close.

Table 4: Average test scores for all incoming School of Engineering students from 2009-2019, regardless of high school type (population mean)

	Incoming	Graduated
avg calc readiness score	17.44	19.08
avg ACT	27.71	28.52
avg ACT Math	28.19	29.26

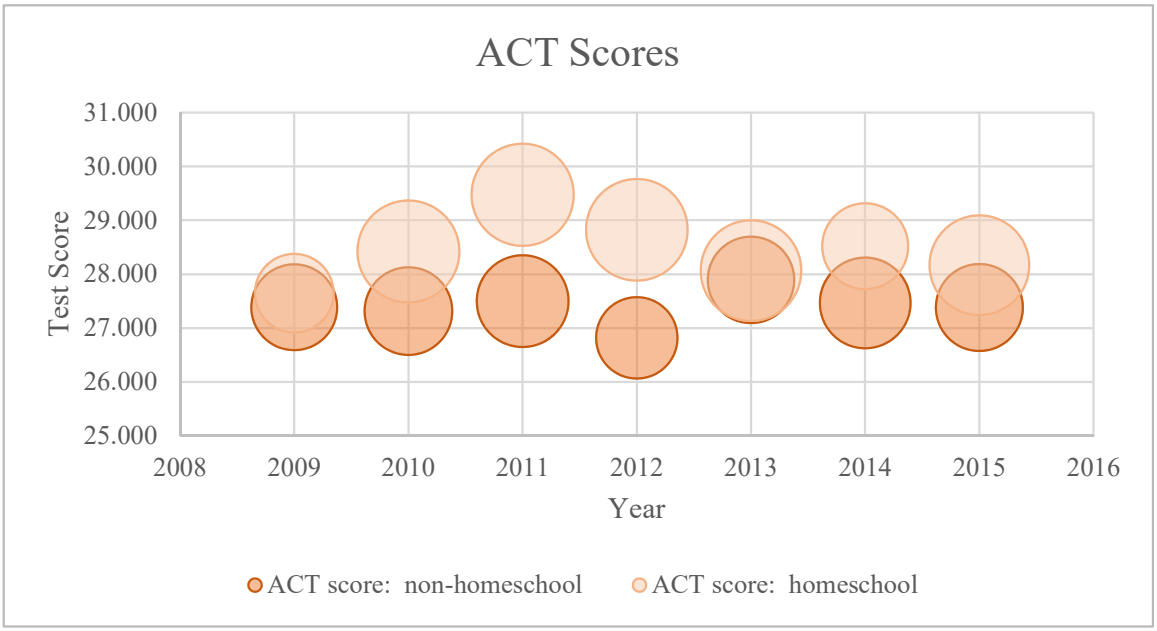

Figure 1: Composite ACT scores of homeschooled vs. non-homeschooled students–the center of each bubble marks the average score for that year's incoming class and the width of the bubble is the standard deviation. A perfect ACT score is 36.

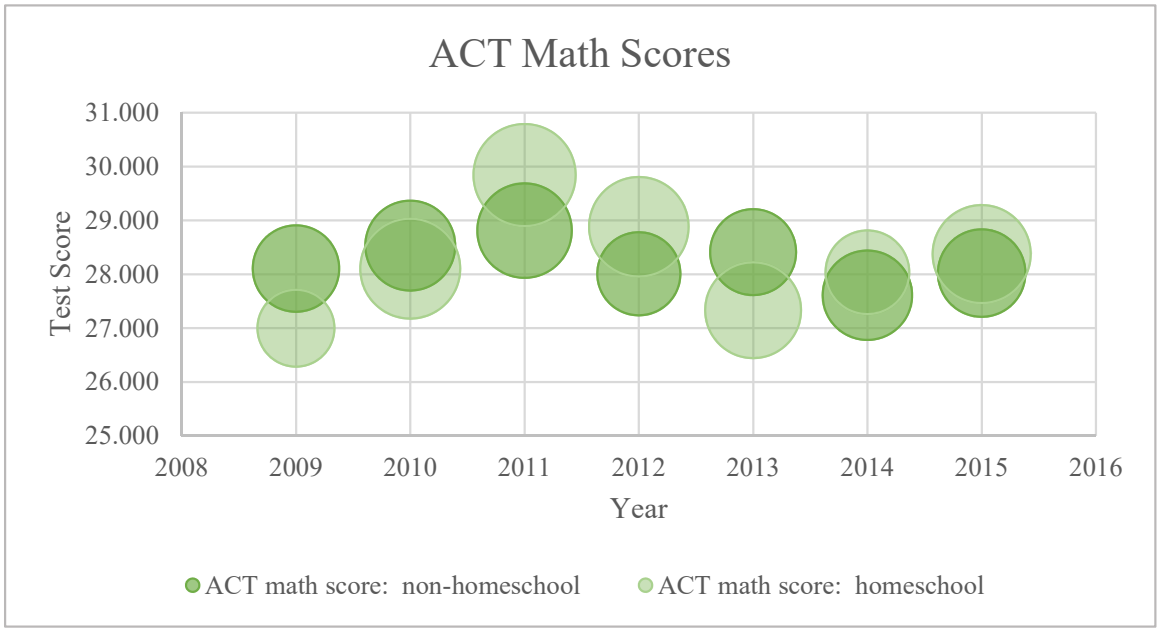

Figure 2: ACT Math scores of homeschooled vs. non-homeschooled students–the center of each bubble marks the average score for that year's incoming class and the width of the bubble is the standard deviation. A perfect ACT score is 36.

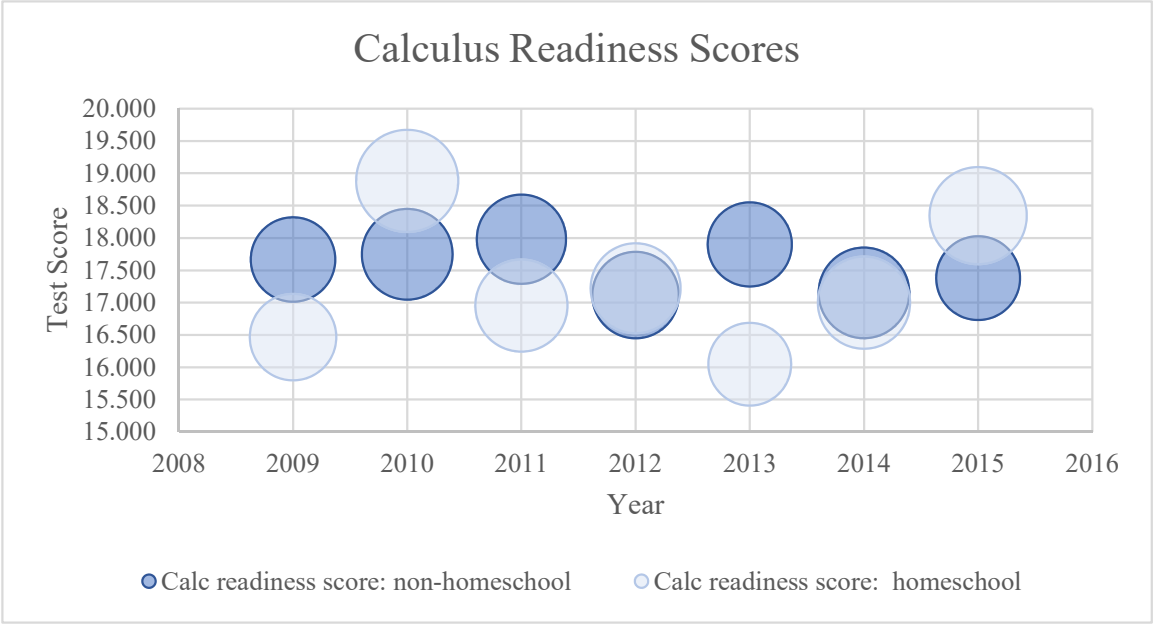

Figure 3: Calculus readiness scores of homeschooled vs. non-homeschooled students–the center of each bubble marks the average score for that year's incoming class and the width of the bubble is the standard deviation. The test is scored by number of questions answered correctly out of 25.

3.2 Retention: Comparing Homeschoolers to Others

Table 5: Retention in the school of engineering for incoming students from 2009-2014

	Homeschoolers	Non-Homeschoolers
number of graduates in ENG	146	406
number started in ENG	257	985
Percentage graduated in ENG	57%	41%

The second comparison to be made between homeschoolers and others is to see whether one group is more likely than the other to be retained in the engineering program, which is considered the primary metric of success in this study. The fact that homeschoolers have similar math readiness scores is interesting when coupled with the information found in Table 5, which shows retention rates for all of the students who started in the School of Engineering since 2009. It is clear from this table that homeschoolers have higher retention rates–on average 16 percentage points higher than the non-homeschooled students. Figures 4 and 5 depict the retention data separated by year. Figure 4 shows the percentages of homeschooled and non-homeschooled

students retained from each freshman class for the years 2009-2015. Here you can see that homeschooled students are consistently retained at a higher rate than their non-homeschooled peers. Figure 5 shows the same data in a different format with actual student numbers shown. Since homeschooled students make up 1/5 to 1/4 of the student body, their numbers are lower, but as can be seen by the comparative widths of the bars, they are more likely to be retained. This view makes the visual point of how less than half of non-homeschooled students are retained, while the majority of homeschooled students are retained each year, consistently.

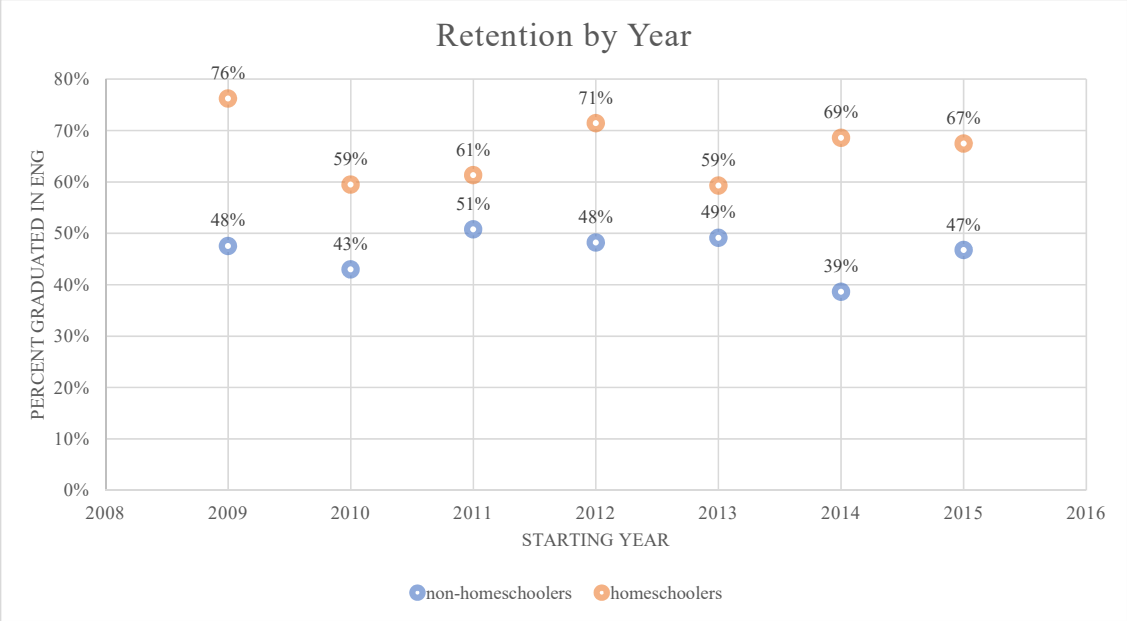

Figure 4: Retention rate (percentage) in the School of Engineering and Computer Science by starting year for homeschoolers (orange) and non-homeschoolers (blue)

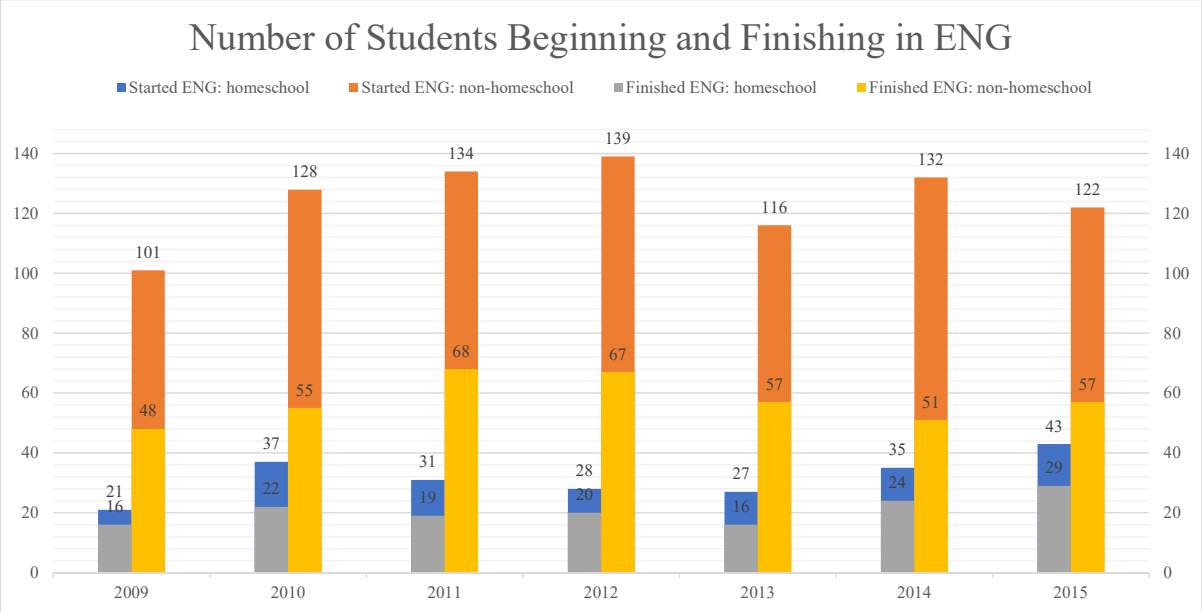

Figure 5: Retention (in the School of Engineering and Computer Science) of homeschooled and non-homeschooled students by starting year with actual student numbers. Note that at least half of all non-homeschooled students leave the School (orange bar), while the percentage is significantly smaller for homeschooled students who start in engineering (blue bar).

4 Discussion and Future Work

The result of this research shows that homeschooled students studied have similar math readiness coming into college compared to their non-homeschooled peers, but they are still more likely to be retained in the engineering program, with a retention rate 16 percentage points higher than that of other students who declare engineering as freshmen. This indicates that homeschooled students are not disadvantaged compared to their academically comparable peers but rather seem to hold some advantage with respect to retention. While we know from experience that strong math preparedness is predictive of student success in our engineering school, these results suggest that there may be other factors in a homeschool K-12 education that are bolstering resolve and achievement in the engineering program.

What differentiating factors in a homeschool education have led to the results presented in this article merit further research in the future. Toward this end, I propose one hypothesis: that homeschooling naturally encourages the characteristics of the independent learner, and those characteristics are indicative of success in both college and engineering. While I am unable to

directly investigate the truth of this hypothesis using currently available data, I would like to use this space to engage in some literature based speculation on the topic, in hopes of inspiring future work.

4.1 The importance of becoming an independent learner

In education literature, it is widely thought that it is better for a student to become an independent or autonomous learner vs. a passive or shallow learner. The Accreditation Board for Engineering and Technology (ABET) lists 7 desired student outcomes for graduates of accredited engineering programs [7]. The statement of outcome 7 echoes the engineering education community's high value on independent learning: "an ability to acquire and apply new knowledge as needed, using appropriate learning strategies." This value of independent learning shows up under many names, including such terms as "self regulated learning," "self directed learning," "learning how to learn," "autonomous learning," etc.

Field et al. [8] state that there is both evidence and psychological theoretical backing for the idea that promoting a student's autonomy increases his or her well being, arguing that the deliberate cultivation of independent learning abilities increases a student's sense of autonomy and subsequently his or her well being and academic success. Thus, it is a worthy goal of the educator to do what he or she can to encourage students to become more independent learners.

4.2 Independent learners and homeschooling practice

There is evidence to suggest that the homeschooling lifestyle tends to impart independent learning skills to its students [9, 10], and that engineering freshmen coming from a homeschool background are therefore more likely to take responsibility for their own learning [8]. This is one possible reason why the homeschooled students from this study succeeded in engineering school at a higher rate than their equally mathematically equipped non-homeschooled peers.

According to [8] and [11], some important characteristics of an independent learner are:

- Critical reflection
- Self-awareness (especially related to own learning needs and interests)
- Self-confidence and self-reliance
- Curiosity
- Taking responsibility for own learning
- Taking action to receive knowledge or acquire skills
- Working creatively with complex situations
- An ability to work with others to enhance the depth and breadth of learning
- An ability to identify when it is appropriate to seek the assistance of others

The authors of [8] note that the characteristics listed above are often wrongly assumed by college faculty to be present in first year students. This is especially the case if those students have spent

their academic lives in traditional classroom style education, where the learning process is highly structured and the expectations for independence and maturity are relatively low. Alternatively, longitudinal studies of homeschooling students and families repeatedly label homeschoolers as independent learners and thinkers [9, 10], with parents identifying and encouraging children's natural creative interests and choosing resources to help them develop. According to these case studies, a typical homeschooler tends to be heavily involved in making decisions regarding his or her own curriculum and schedule, working closely with his parents. He is primarily responsible for getting work done in a timely manner and meeting the requirements set by curriculum, parents, and state regulations. While it is possible to teach independent learning skills in a traditional classroom, the homeschooled student typically must develop them naturally due to the educational environment.

It is my hypothesis that responsibly executed homeschooling uniquely and organically encourages the "independent learner characteristics" in the bulleted list above to an extent that other forms of education do not or cannot because the very nature of home education tends to be more individualized and student directed compared with a traditional classroom setting. If so, this is one possible explanation of the significantly higher retention in the engineering program of homeschooled students found in this study.

There is much discussion in the education community about how to help students become more independent learners even at the college level, with numerous recommendations on pedagogical tactics [12, 13] and various degrees of recorded success. While homeschooled students perhaps are more likely to learn some of these skills earlier in their education, this should only serve to encourage our efforts to raise our expectations for all students as individual learners, identify and encourage them to pursue problems they are interested in, and reward curiosity and independent thinking throughout our students' education.

5 Conclusion

In this study, data from 1,930 students, 426 of whom were homeschooled, who declared engineering upon arrival at the same university were considered. The data consisted of math placement and standardized test scores for incoming students, high school type, and college graduation date and major. Comparisons were drawn between homeschooled students and others using the metrics of math readiness and retention in the engineering program. The two results of this data study can be summarized as follows.

1. Homeschooled students and non-homeschooled students studied come to engineering school with similar levels of academic and math preparedness.
2. Homeschooled students studied have significantly higher retention rates compared to non-homeschooled peers (16 percentage points higher on average).

Taken together, these two results lead to the following conclusion: homeschooled students are more likely to be retained in engineering school for reasons other than superior math preparedness.

A literature-based hypothesis as to why this might be the case has been offered, but more specific survey data and/or qualitative study would be necessary to draw a firm conclusion as to why

homeschoolers have such relatively high retention rates in undergraduate engineering programs.

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