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RESEARCH BRIEF

Predicting Student Success Using In-Program Monitoring

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Objective. To determine whether admissions data alone adequately predicts student success in the first-year doctor of pharmacy (PharmD) curriculum or whether academic monitoring and intervention has greater value toward successful completion of first-year coursework.

Methods. A systematic evaluation of the literature assessing student success was performed to ascertain historical evidence of student success metrics. We then retrospectively analyzed internal admissions data and first-year outcomes for our pharmacy classes of 2016-2019 using available data. We conducted an interim evaluation of voluntary academic monitoring and mentoring with the hypothesis that admission data alone cannot predict student success in early foundational coursework, and intentional intervention might improve success.

Results. Pre-pharmacy grade point average (GPA), science GPA, Pharmacy College Admission Test (PCAT) score, and prior degree status each retain some predictive value regarding success, and combinations of these factors may improve the ability to predict student success in early foundational coursework. There remains a significant, and perhaps insurmountable, gap in identifying quantitative metrics that forecast student success. Although admission data can stratify incoming students based on predicted academic ability, early monitoring and intervention provide an actionable means for enhancing student success in first-year coursework.

Conclusion. Quantitative academic measures, such as PCAT scores and GPA, historically have demonstrated limited value in predicting student success. While these measures allow stratification of predicted academic performance among incoming students, monitoring of first-year, institution-specific data, such as midterm grades, can direct intentional intervention and remediation strategies that may provide more benefit to ensure students succeed.

Keywords: student success, admissions data, mentoring, monitoring

INTRODUCTION

Pharmacy schools consistently struggle to define qualified candidates capable of becoming highly competent practitioners during the admissions process. As the number of PharmD program grows, competition for top students increases. Thus, greater importance is placed on identifying those candidates who are most likely to be successful, intensifying the stress on admissions committees. Admissions committees are dependent on their faculty colleagues to ascertain what constitutes "success" and what metrics included in the application materials are most important to consider when identifying qualified applicants. For these reasons, many studies have sought to determine which factors have proven most useful in predicting success when selecting students for admission. What happens when admissions committees admit students who do not meet institutional historical standards? How do we help those students succeed?

A host of studies have shown that pre-pharmacy GPA, math/science GPA, PCAT score, and prior degree status each independently correlate with success. Importantly, not one of these factors performs as an absolute predictor, and because of these observations, a few studies have evaluated the predictive value of combinations of factors.[1,2] Further, it appears few programs use these data post-admission to focus academic monitoring. The consequence of poor student success has both financial and emotional costs to the student and the college. Therefore, by using evidence-based approaches to identify students who might struggle and then implement intentional monitoring, we may improve our student success and well-being.

The primary objective of our study was to seek the factors or measurements collected with admission information that most reliably predicted success in the first-year,

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basic science component of our PharmD program. Our secondary objective was to determine whether in-program monitoring of student progress resulted in improved outcomes. We found that students who struggle in the first-year, foundational sciences portion of our curriculum are likely to continue struggling, often resulting in failure to achieve timely matriculation through our program.

METHODS

We used published data and retrospective programmatic data for this study. The literature search included the following terms: pharmacy, predictors, success, failure, academic, struggle, and professional school. Of the resulting articles, those published in the past 20 years were collected and analyzed. Those most relevant to our hypothesis were reviewed further, and the data were extracted and organized into categories (pre-pharmacy GPA, math/science GPA, PCAT, and prior degree status) based on the predictor of success each study supported or refuted. The findings of these studies are referenced within this article.

Second, we used an institutionally approved IRB protocol to examine admissions and first-year grade data from our institution's classes of 2016-2019. Those admissions data included: GPA, science GPA, PCAT, chemistry PCAT sub-score, biology PCAT sub-score, math PCAT sub-score, and interview scores. The outcomes data to which these parameters were assessed was the combined numerical grade in two semesters of the first-year Physiological Chemistry and Molecular Biology (PCMB) course.

Admissions data (classes of 2016-2018) were analyzed by logistic regression to estimate the probability that a student placed in the top 20% of the combined PCMB class completed in the first year of the curriculum. We eliminated any student for whom we did not have a complete data set (n=3). Science GPA was an important predictor and was included in the final models.[3] A feasible solution (FS) algorithm was then implemented with class of 2016 and 2017 data to search for more nuanced interactions that could be added to a model with science GPA to better estimate the probability of being in the top 20% of PCMB total points. Using R programming language, the FS algorithm analyzed multiple models using science GPA, biology PCAT sub-score, and chemistry PCAT sub-score, including potential interactions among those factors. Including these parameters in the model with their interactions, the area under the curve (AUC) estimate of the receiver operator curve (ROC) was 90%.[4] We then reasoned that students with the lowest science GPA and PCAT sub-scores were likely to perform poorly. Second, we employed an unbiased regression analysis using IBM Watson Analytics (Armonk, NY). In the "exploration mode," Watson was asked to identify which admissions factors predicted the "target" variable; in our case "total PCMB points."

Using the information derived from the analyses above, we sorted students (classes 2016-2019) by science GPA, then PCAT, then GPA using Microsoft Excel (Redmond, WA). We focused on the students in each class predicted to perform poorly and followed the matriculation of each class (2016-2019) for suspensions due to poor academic performance and predicted on-time graduation rates.

RESULTS

As expected from this evaluation, neither GPA nor PCAT scores from admissions data adequately predicted success in the first year of the curriculum (PCMB score). We used Watson analytics and regression analysis followed by an FS algorithm to determine whether predictive measures of success could be identified for our cohort of students using individual and combinations of metrics previously identified as predictive. Using the outcomes from both Watson and FS analyses, we found that the stepwise combination of PCAT, GPA, and science GPA had the best predictive power in determining successful transit through the first-year curriculum, similar to said data (Figure 1).[1] Interestingly, we observed from the FS interactions that lack of a bachelor's degree (data not shown) was indicative of success in our curriculum, contradicting a notion that Chisolm and colleagues addressed.[16]

As shown in the heat map in Figure 1 (wherein darker shading represent the best performance in PCMB), the Watson analytics analysis showed that student GPA and PCAT scores were the optimal predictors of performance ("total"). The predictive strength of these parameters is 36.4% and is followed closely by chemistry PCAT and science GPA, or science GPA and PCAT; both having a predictive score of 36.3%. Science GPA alone had a predictive power of 25.5%, while PCAT alone had a predictive power of 16.3%. Figure 2 demonstrates that FS could uncover the nuances of both PCAT and GPA that contribute as predictors of success. Adding the interaction of biology and chemistry PCAT sub-scores modestly improves the R^2 value of the science GPA model alone (0.34 to 0.36). Importantly, a high chemistry PCAT sub-score can rescue a low biology sub-score in this model, but the reverse was not true.

Because the unbiased Watson analysis and FS interactions converged on science GPA and some elements of the PCAT, we used these variables to sort students in each class admitted between 2016 and 2019 based on science

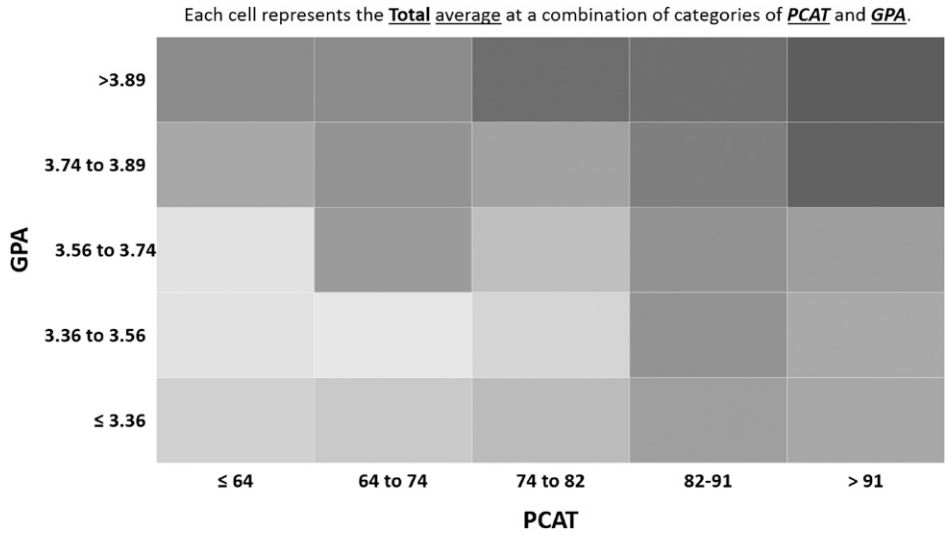

Figure 1. Watson analytics was used to determine admissions factors that predict success in the first academic year in our college. Pharmacy College Admission Test (PCAT) score is indicated on the bottom axis, and grade point average (GPA) on the left axis. Darker shades indicate the combinations that best predict success in Physiological Chemistry and Molecular Biology course (PCMB). "Total" is the combined score of both semesters of PCMB and darker shading is related to higher PCMB scores.

GPA, then PCAT, then GPA in Excel. We intentionally tracked the top 20 and the bottom 20 students from the classes of (2016-2019) in each of the foundational sciences classes delivered in the first academic year (Physiology, Pharmaceutics, and Physiological Chemistry) to follow their progression. We found that the combination of overall PCAT score, GPA, and science GPA was able to identify most of the students who did not progress through the curriculum on time across four years of data. However, several students in each class that we evaluated did not progress even though the quantitative data suggested that they should, and the converse also was true (Table 1). Importantly, in the last two classes (2018-2019), the use of science GPA, PCAT, and GPA missed

Source	FDR LogWorth	FDR PValue
sci gpa	9.638	0.00000
chem pcat	5.529	0.00000
bio pcat*chem pcat	2.046	0.00899
bio pcat	1.224	0.05971

Figure 2. Feasible Solutions analysis of admission data (Classes 2016 and 2017) demonstrates that science GPA (sci gpa), chemistry PCAT sub-score (chem pcat) and the interaction of biology (bio pcat) and chemistry PCAT sub-scores best model success in PCMB. False Discovery Rate (FDR) is the method of demonstrating type I error rate in null hypothesis testing when conducting multiple comparisons. LogWorth is the $-\log_{10}$ of the FDR p value for the ease of comparison of the contribution of each component of the model.

all of the suspensions. Also, several of those suspensions, although for academic shortcomings, may have been the result of an underlying personal issue. As a result of these data and prior experiences, we initiated a college-wide, voluntary mentoring program with the class of 2019 (Fall 2015) under the hypothesis that an early-warning system launched during a mid-semester grade review may better serve to intervene and direct remediation rather than relying on admissions data to predict student success.

Our analysis then followed a single year (2015-2016) of the mentoring program. Importantly, we found that mentoring among groups was not consistent, as reported by faculty mentors. Further, most students did not take advantage of their faculty mentors. From this class alone, we observed a similar number of students who did not progress (n=4/131; Table 1) or struggled to progress (n=11/131; data not shown) as we did for the classes of 2016-2018 who did not have the advantage of a voluntary mentoring program. Although the combination of overall PCAT score, GPA, and science GPA did not predict the four students who did not progress with the class of 2019, we did predict about half of the students who were identified by our college academic performance committee for discussion of progress at the end of Spring 2016. This is somewhat better than the 36% predictive power we anticipated. Using end-of-term survey data, we found that only about half of the class of 2019 took advantage of mentoring opportunities.

Finally, it is noteworthy that our admissions process has changed in the past several years. Multiple mini-interviews (MMI) replaced group and individual interviews

Table 1. Assessment of Actual and Predicted Student Success in Our College Following Year 1 Success

	Class of 2016	Class of 2017	Class of 2018	Class of 2019
Class Size – New Admissions	137	135	137	131
Suspensions After P1 Year	5	3	7	4[a]
Predicted Suspensions by GPA/science GPA/PCAT	4	2	0	0
Predicted On-time Graduation Rate (%)	88	96	96	N/A

[a] Mentoring program

for the classes of 2018 and 2019 under the pretext that these data would improve our admissions decision-making process.[17] Our institution has struggled to determine how to best use the rich data that the MMI provides to predict success in our program and, subsequently, in practice. Our college faculty believe that the MMI can indicate those students who excel in critical thinking, assimilation of data, and communication, thereby providing another quantitative measure that can be mapped to programmatic outcomes and career success. Conversely, those students who score poorly in the multi-station interviews would be predicted to struggle in a variety of academic activities including standardized patient encounters, objective structured clinical exams, and interpersonal communication. However, retrospective review of the last two years of MMI admissions data compared with progression indicated no apparent relationship with success. For the class of 2018, the top 20 students had an average GPA of 3.96 (out of 4; end of year 1) and an average MMI score of 47.7 (total=70) with a standard deviation of +/- 7 while the bottom 20 students who entered in that class had an average GPA of 2.59 and an average MMI score of 43.5 +/- 6.2. In the class of 2019, the top 20 students had an average GPA of 4.0 (end of year 1) and an average MMI score of 41.1+/- 10.7 while the bottom 20 students who entered in that class had an average GPA of 2.74 and an average MMI score of 44.9+/- 6.4. Thus, more MMI data will be needed to determine the usefulness of these data in admission decisions and monitoring of progression.

DISCUSSION

Our review of the literature revealed that multiple factors appear to be correlated with pharmacy student academic success. Pre-pharmacy GPA, math/science GPA, PCAT, and prior degree status have all been identified as having predictive value, but no single factor, or combination of the four, was able to identify all students who eventually experienced failure in our program. Like others, we found (Figures 1 and 2) that only a portion of student success could be explained by use of PCAT, GPA, and science GPA. No matter what metrics were used to measure success, there were always students who did not succeed, even though the quantitative data suggested that they should, and the converse held true. Specifically, one might suspect that a bachelor's degree requirement would result in an academically mature student body and, therefore, reduce the number of students who struggle. Further, having a prior degree also would create consistency among health care professional programs, specifically medicine, dentistry, nurse practitioner, physical therapy, and physician's assistant that all have this requirement.[18] However, when surveying our candidates, regression data suggested that possession of an undergraduate degree is negatively correlated with success and was not a factor used as a feasible solution. From this observation, we suspect that the students who enter without a degree may be especially motivated to succeed and have chosen to accelerate their time to receiving a degree to reduce costs. Given these data, we also infer that the factors predictive of success may be largely institutional specific, making globalization of the best factors to consider with regards to student success challenging. Furthermore, it becomes difficult to compare these variables across different colleges of pharmacy because each institution has subtle variations of requirements for admission. For example, PCAT has been noted as one of the most reliable predictors of student success, yet there are a few colleges of pharmacy that do not require a PCAT score for admission into their program.[14] Going forward, as institutions strive to identify the most qualified candidates for admissions, it will be important to bear in mind that the factors best predictive of success may vary based on these subtleties. Identifying the combination of admissions variables that work best in one's own institution will be essential for individual programs.

Our own efforts to identify students with a propensity to fail were not successful using solely admissions or pre-pharmacy data. Thus, we sought to find other indications that would improve student success. For the purposes of this study, success was defined as the timely completion of first-year foundational sciences coursework. We used the combined scores from the Physiological Chemistry and Molecular Biology sequence to rank students in the classes of 2016-2018. We then evaluated the metrics that predicted the grades of bottom students using two models

and found that a combination of factors (science GPA, PCAT scores, and GPA) were the best in determining lack of success in first-year, foundational course work. We then tested this sequence of factors with the class of 2019. As many have shown before, we did not achieve 100% success (Table 1). We correctly predicted some who struggled, but none who did not progress. Further, we asked whether the admissions MMI sub-category predicted success, and we did not find a relationship. However, we only had limited data to consider. Importantly, it seems that in-program information is more valuable (mid-semester grades) in directing intervention and remediation.

Many studies have been conducted to evaluate the predictive value of individual admissions criteria toward multiple outcomes measures, such as academic performance, timely matriculation to degree, or NAPLEX scores.[1,5-7] While there is consensus in that there are a number of important predictive factors to consider, identifying a single best predictor of success has proven elusive. It also remains evident that no one factor can conclusively determine whether a candidate will be successful in a PharmD program. While there are objective factors that give some indication of success, the factors most indicative of success may be more subjective in nature.

Among the articles we reviewed, the objective three factors frequently studied with regard to their predictive value of success in a PharmD program are pre-pharmacy GPA, math/science GPA, and PCAT. The first factor we considered, pre-pharmacy GPA, is continually regarded as one of the best predictors of success, regardless of the defined endpoint of success. Studies continually demonstrate that it is regarded as a stable and reliable factor to consider when making admissions decisions.[6,8] The assumption is that past academic performance will be indicative of success in a professional degree program.[2] Studies have demonstrated that pre-pharmacy GPA is significantly positively correlated with first-year pharmacy GPA and NAPLEX scores upon graduation from a PharmD program.[5,9]

Second, it seems intuitive that the math/science GPA sub-score would be useful for admissions committees to consider because these courses are most closely aligned with the coursework a student would be expected to complete in a PharmD curriculum. Several studies have concluded that math/science GPA is a predictor of academic success with regard to first-year pharmacy GPA, and it has been negatively associated with academic dismissal from PharmD programs.[6,7,10,11] Like the overall pre-pharmacy GPA, the pre-pharmacy math/science GPA has been shown to be one of the best predictors of student success in the first year of a PharmD program.[12] Our own data suggest that GPA, specifically science GPA, can be used as part of a model to predict success in foundational coursework.

Third, the Pharmacy College Admissions Test (PCAT) is also a well-studied predictor of success. Composite PCAT scores are also positively correlated with first-year pharmacy GPA and identified as a valuable predictor of success in the first year as well as overall success in the PharmD program.[6,13] Other studies have demonstrated that PCAT sub-scores should be considered because poor sub-scores in all categories have been associated with poor grade attainment in the PharmD curriculum.[10] However, there are some institutions that do not require a PCAT score for admission into the program, despite the literature that regard this score, and associated sub-scores, as validated indicators of success.[14] Our data find that biology, and especially chemistry, PCAT sub-scores contribute to our strongest model that predicts success in PCMB.

Further, a student's prior degree status appears to have some predictive value regarding success in a PharmD program. Students who have a bachelor's degree prior to entering a PharmD program are typically older and thought to be more mature, both of which can impact academic performance. Twenty years ago, Chisholm and colleagues showed that holding a bachelor's degree prior to admission into a PharmD program was predictive of success in the first year. More recent studies have echoed this finding that students possessing a bachelor's degree have a higher GPA in first-year pharmacy curriculum.[5,11] Our data do not support prior findings, but this observation may be the result of non-academic factors. Furthermore, the type of degree held by a student also may predict success. Attaining a bachelor of science degree compared to a bachelor of arts was associated with a higher first-year GPA.[15] In contrast, a study by Thomas and Draugalis did not indicate that prior degree status was a significant predictor of academic success.[16] While a prior degree may not be a program-specific requirement for admission into a PharmD program, it may still be a useful factor to consider when making admissions decisions.

Finally, Alston and colleagues used both correlation and regression models to determine combinations of factors that predicted students likely not to progress past the first year of the PharmD curriculum. In contrast to other studies, Alston and colleagues also utilized in-program variables in their analysis, including students' scores on exams 1-5 in a basic science course, pharmacy GPA at the end of semester one (GPA1), pharmacy GPA at the end of semester two (GPA2). The regression model label, "test-taking ability" was unique, in that it suggested that a student's score on the first exam in a basic science course was shown to be a standalone indicator of failure and may function as an early-warning sign of student struggle.

Using in-program data might allow for a program to identify students at risk for failure by the end of the second semester with a reasonable level of certainty.[1] Interestingly, failing a pre-pharmacy course was indicative of poor outcome as described by Hansen and colleagues.[2] Overall, the results of our literature review suggest that in-program variables may be better predictors of student success than pre-pharmacy variables. Given these data, we sought to determine whether PCAT and GPA scores might stratify incoming students and provide an objective method for identifying students who should be monitored, and when appropriate, receive targeted mentoring and remediation.

This study has forced us to revisit our own definition(s) of success and how we expect to monitor success. As we install a new curriculum, we envision more student accountability for learning, and we will measure learning with traditional subject-specific examinations as well as mid-program competency exams. Our new curriculum will launch with less traditional lecture time and more self-paced learning outside of the classroom spaces. Therefore, we must find improved methods for tracking student success. In this study, we found that identifying students in danger of failure may be accomplished with greater certainty using in-program rather than solely admissions data. Therefore, instituting formal academic monitoring and mentoring should strengthen student success. Equipping students with the necessary support and skills to adapt to a rigorous curriculum will be crucial in ensuring that they can successfully progress through a PharmD program and have professional success as a lifelong learner.

CONCLUSION

It is evident that admissions data alone cannot identify those candidates who are likely to struggle in a PharmD program, especially considering these data may be institution specific. By screening incoming students using admissions data, we can create a "watch list" that can be paired with in-program data to identify students who may benefit from intervention to nurture them toward success. In the future, mentoring and monitoring will be most important to ensure timely matriculation through PharmD programs.

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