Prerequisite Courses as a Predictor of Biomedical Science Courses achievement in Mahidol Dental Students

Somkiat Koohawayrojanapakorn[1], Nannapat Koonthaugthao[2], Somsak Mitriratanakul[3], Ratchapin L Srisatjaluk[4]

[1] *M. Ed. (Educational Measurement and Evaluation)Education and Academic Office, Faculty of Dentistry, Mahidol University*
[2] *B. A. (Business Administration) Education and Academic Office, Faculty of Dentistry, Mahidol University*
[3] *Ph.D. (Oral Biology) Department of Masticatory Science, Faculty of Dentistry, Mahidol University*
[4] *Ph. D. (Microbiology and Immunology) Department of Oral Microbiology, Faculty of Dentistry, Mahidol University*

Objective: The study investigated whether the grade received in the basic science prerequisites can predict the dental student performance in the biomedical science courses.

Materials and Methods: The data were grades of the second-year dental student of Mahidol University who completed the courses in the academic year 2014 (n = 111). The grades earned in 7 prerequisites in their first year were considered as independent variables. The dependent variables were the grades of 5 biomedical science courses in the second year requiring these prerequisites. For each basic science prerequisite, the grade was analyzed for the predictive ability of the corresponding target course using the Pearson's correlation coefficient and the multiple regression analysis.

Results: A correlation was found between the grade received in the prerequisites and the biomedical science courses. The best predictor was Organic Chemistry prerequisite on Biochemistry ($R^2 = 0.554$). Grades earned in prerequisite courses, i.e., Organic Chemistry, Process of Life, Physics for Medical Science, Statistics for Medical Science provided minimal predictive ability for Biochemistry Laboratory, Introduction to Genetics, Physical Principles in Life Science and Dentistry, and Biostatistics courses ($R^2 = 0.169, 0.197, 0.181$, and 0.142, respectively). Essential Biology had no impact on Introduction to Genetics. Similarly, General Physics Laboratory and Basic Physics for Medical Science had no impact on Physical Principles in Life Science and Dentistry.

Conclusion: For Mahidol dental students, grades in some basic science prerequisites can significantly predict the success of the target biomedical science courses. Organic chemistry was the most significant prerequisite as a predictor for biochemistry.

Keywords: prerequisites, predictor, biomedical science, dental education, dental students, student achievement

How to cite:

Correspondence author: Ratchapin L Srisatjaluk
Faculty of Dentistry, Mahidol University 6 Yothi Street, Ratchathewi, Bangkok 10400, Thailand
Tel: +66 (0) 2 200 7805 Fax: +66 (0) 2 200 7804 Email: ratchapin.sri@mahidol.ac.th

Introduction

Biomedical science, considered as a foundation of the contemporary dental curriculum is complex and continually changing. Learning in biomedical science will be based on a presumption of an achievement of a basic chemistry, physics, biology and mathematics as prerequisites. For undergraduate dental curriculum at Mahidol dental curriculum, biomedical science courses are mainly taught in the second and the third year of the six-year program. Some is integrated in the fourth to sixth clinic year. The first year of enrollment courses are focused on General Education including Social Sciences and Humanities, Languages, and Basic Sciences and Mathematics. The percentage of hours of basic and biomedical science instruction in the total of Mahidol dental curriculum is 19%, which is comparable to those in some countries, e.g. the report in 2000 from USA is 17.3% [1]. The major goal of the basic and biomedical science curriculum is to provide the knowledge in related subject areas which is prerequisite to understand and perform diagnostics, therapeutics, and clinical treatment of patients [2]. Biomedical science has transformed from discipline-based to multidisciplinary work to solve complex problems of significance. The teaching and learning methods are also designed to encourage the students' development on critical thinking and life-long learning. For dental students to be successful in integrating biomedical science and clinical science concepts and practices, it is important that they have a strong foundation in basic sciences [3]. To improve the quality of undergraduate preclinical science education in dental curriculum, it requires a better understanding of approaches or factors that lead to student success and enhanced learning.

Like other college curricula, prerequisites are standard and establish the preconditions for course enrollment and serve as course preparedness. Applicants to Mahidol dental school are coming from diverse backgrounds of basic science preparation from high schools. The basic science courses in the first year of dental school prepared them for the target courses of biomedical science in the following years. The underlying assumption is that students learn information or skills in the prerequisite course upon which the subsequent courses will build. Alternatively the completion of the prerequisite course produced a more mature, and skillful student who is better prepared to face the rigors of the target courses. Students who are successful in prerequisite courses might be expected to be success in the course that requires the prerequisite.

There are still few studies concerned the impact of prerequisites on student academic performance in biomedical courses of dental curricula. Thus, it is worthy for our dental school to assess the significance of the dental student performance of first year prerequisite courses on the basic biomedical science courses in our dental curriculum. This study investigated whether the grade received in the first year prerequisite basic science courses can predict the student performance in the upper-level biomedical science courses.

Materials and Methods

With the approval of the Institutional Review Board of the Faculty of Dentistry / Faculty of Pharmacy, Mahidol (COE. No. MU-DT/PY-IRB 2016/016.0308), the student data were collected from the second year dental students who completed the biomedical science courses at Faculty of Dentistry Mahidol University in the academic year 2015. Total of 111 students were 33 female (29.73 %) and 78 male (70.27 %), with the age range of 18-19 years. The prerequisite courses analyzed were the 7 basic science courses that the students had been

taken in the first year at the Faculty of Science. These courses were SCCH 122: Organic Chemistry 3 credits; SCBI 113: Essential Biology 2 credits; SCBI 123: Process of Life 3 credits; SCPY 110: General Physic Laboratory 1 credits; SCPY 153: Basic Physics for Medical Science 2 credits; SCPY 154: Physics for Medical Science 3 credits; SCMA 181: Statistics for Medical Science 2 credits. The target courses were the upper-level biomedical science courses that they took in the following second year at the Faculty of Dentistry. Those were DTBC 231: Biochemistry 3 credits; DTBC 232: Biochemistry Laboratory 1 credit; DTBC 234: Introduction to Genetics 1 credit; DTBC 235: Physical Principles in Life Science and Dentistry 1 credit; DTID 233: Biostatistics 1 credit. The student performance in each course was measured by the grade achieved during the student's first time enrollment. The grades earned in the biomedical science courses were considered as dependent variables. The independent variables were the grade received by their prerequisite courses. Course letter grades were coded with A=4, B+=3.5, B=3, C+= 2.5, C=2, D+=1.5, D=1. Organic Chemistry is prerequisite for Biochemistry and Biochemistry Laboratory; and Statistics for Medical Science is prerequisite for Biostatistics. The group of corresponding prerequisites, i.e., Essential Biology and Process of Life is for Introduction to Genetics; and General Physic Laboratory, Basic Physics for Medical Science, Physics for Medical Science is for Physical Principles in Life Science and Dentistry.

The correlation coefficients (r) were analyzed using the Pearson's correlation. The stepwise multiple regression analysis was used to determine the β coefficient. In the stepwise analysis, *t* tests are used to indicate whether a prerequisite has a significant prediction values. Significance was considered at 0.05 levels. Statistical analysis were conducted using the SPSS Statistics Version 18 (SPSS, Inc, USA)

Results

Success rates of students who met the prerequisites and the target courses are 100%. Grade distribution of the 7 prerequisites and their 5 target courses were shown in Table 1-4. The average grades of the class in the basic prerequisites and the target biomedical science courses were shown in Figure 1. Pearson's correlation indicated the grade received in the prerequisite courses was positively related to subsequent performance in the target biomedical courses (Table 5). Organic Chemistry tended to be the most highly correlated to Biochemistry (r = 0.744), while the General Physic Laboratory showed the least correlation to Physical Principles in Life Science and Dentistry (r = 0.193)

We further evaluated whether the grade received in the prerequisite courses predicted performance in the target biomedical science courses. Results from the stepwise multiple regression analysis, shown in Table 6, indicated that some prerequisite courses were significant predictors of their biomedical courses. The best prediction in this study was an Organic Chemistry prerequisite on a Biochemistry grade ($R^2 = 0.554$). Grades earned in prerequisite courses, i.e., an Organic Chemistry, Process of Life, Physics for Medical Science, Statistics for Medical Science provided minimal predictive ability for Biochemistry Laboratory, Introduction to Genetics, Physical Principles in Life Science and Dentistry, and Biostatistics courses ($R^2 = 0.169, 0.197, 0.181,$ and 0.142, respectively). Essential Biology prerequisite had no significant impact on Introduction to Genetics grade. Similarly, General Physics Laboratory and Basic Physics for Medical Science had no prediction ability on Physical Principles in Life Science and Dentistry performance.

Table 1 Grade distribution of the prerequisite-Organic chemistry- and the target courses- Biochemistry and Biochemistry laboratory.

Course grade	Prerequisite		Target biomedical science courses			
	Organic chemistry		Biochemistry		Biochemistry laboratory	
	Number of Students	Percentage of students	Number of Students	Percentage of students	Number of Students	Percentage of students
A	22	19.8	37	33.3	18	16.2
B+	32	28.8	45	40.5	74	66.7
B	26	23.4	12	10.8	19	17.1
C+	11	9.9	8	7.2	-	-
C	12	10.2	9	8.1	-	-
D+	5	4.5	-	-	-	-
D	3	2.7	-	-	-	-
Mean grade ± S.D.	3.06 ± 0.78		3.42 ± 0.60		3.50 ± 0.29	

Table 2 Grade distribution of the prerequisites- Essential Biology and Process of Life- and the target course-Introduction to Genetics.

Course grade	Prerequisite				Target biomedical science courses	
	Essential Biology		Process of Life		Introduction to Genetics	
	Number of Students	Percentage of students	Number of Students	Percentage of students	Number of Students	Percentage of students
A	-	-	17	15.3	17	15.3
B+	1	0.9	12	10.8	34	30.6
B	25	22.5	26	23.4	30	27.0
C+	50	45.0	20	18.0	15	13.5
C	30	27.0	15	13.5	15	13.5
D+	5	4.5	13	11.7	-	-
D	-	-	8	7.2	-	-
Mean grade ± S.D.	2.44 ± 0.42		2.66 ± 0.90		3.10 ± 0.63	

Table 3 Grade distribution of the prerequisites-General Physic Laboratory, Basic Physics for Medical Science, Physics for Medical Science- and the target course- Physical Principles in Life Science and Dentistry.

Course grade	Prerequisite						Target biomedical science courses	
	General Physic Laboratory		Basic Physics for Medical Science		Physics for Medical Science		Physical Principles in Life Science and Dentistry	
	Number of Students	Percentage of students	Number of Students	Percentage of students	Number of Students	Percentage of students	Number of Students	Percentage of students
A	107	96.4	6	5.4	6	5.4	14	12.6
B+	3	2.7	13	11.7	18	16.2	13	11.7
B	-	-	44	39.6	31	27.9	35	31.5
C+	1	0.9	26	23.4	31	27.9	30	27.0
C	-	-	20	18.0	20	18.0	19	17.1
D+	-	-	1	0.9	4	3.6	-	-
D	-	-	1	0.9	1	0.9	-	-
Mean grade ± S.D.	3.97 ± 0.16		2.78 ± 0.58		2.74 ± 0.63		2.88 ± 0.62	

Table 4 Grade distribution of the prerequisite- Statistics for Medical Science- and the target course- Biostatistics.

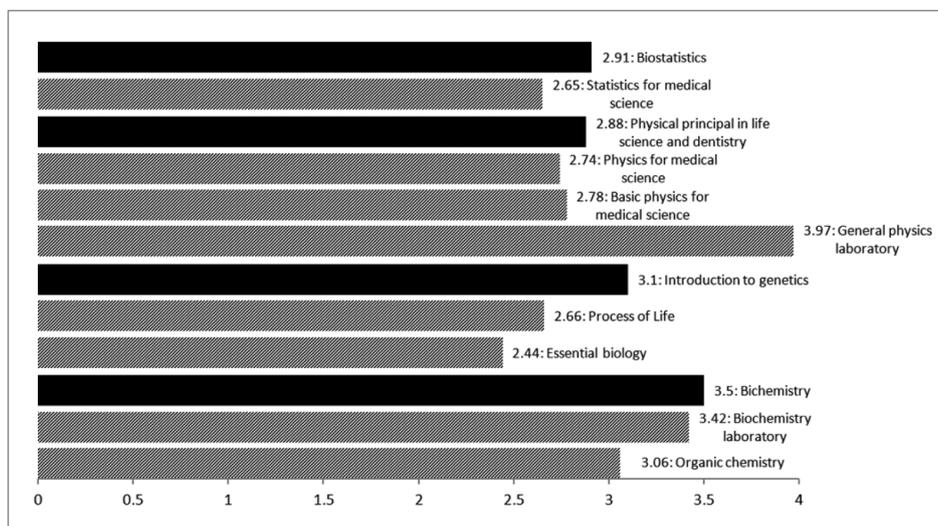| Course grade	Prerequisite		Target biomedical science courses	
	Statistics for Medical Science		Biostatistics	
	Number of Students	Percentage of students	Number of Students	Percentage of students
A	6	5.4	20	18.0
B+	16	14.4	21	18.9
B	19	17.1	24	21.6
C+	39	35.1	12	10.8
C	28	25.2	34	30.6
D+	2	1.8	-	-
D	1	0.9	-	-
Mean grade ± S.D.	2.65 ± 0.62		2.91 ± 0.75	

Figure 1   Average grades in the target biomedical science courses (black bars) relative to their corresponding prerequisites (grey bars).

Table 5   Correlations between the prerequisites and the target biomedical courses.

Prerequisites (first year)	Biomedical science courses (second year)	Correlation Coefficient (r)
SCCH 122: Organic Chemistry	DTBC 231: Biochemistry	0.744*
SCCH 122: Organic Chemistry	DTBC 232: Biochemistry Laboratory	0.411*
SCBI 113: Essential Biology	DTBC 234: Introduction to Genetics	0.387*
SCBI 123: Process of Life		0.443*
SCPY 110: General Physic Laboratory	DTBC 235: Physical Principles in Life Science and Dentistry	0.193*
SCPY 153: Basic Physics for Medical Science		0.307*
SCPY 154: Physics for Medical Science		0.425*
SCMA 181: Statistics for Medical Science	DTID233: Biostatistics	0.377*

* Correlation is significant at $\alpha = 0.05$.

Table 6   The stepwise multiple regression analysis.

Biomedical science courses	Prerequisite courses	B	Std. Error	Beta	p value	R^2
Biochemistry	Organic Chemistry	0.571	0.049	0.744	<0.0001*	0.554
Biochemistry Laboratory	Organic Chemistry	0.152	0.032	0.411	<0.0001*	0.169
Introduction to Genetics	Essential Biology	0.294	0.155	0.197	0.060	
	Process of Life	0.230	0.072	0.330	0.002*	0.197
Physical Principles in Life Science and Dentistry	General Physic Laboratory	0.363	0.341	0.096	0.289	
	Basic Physics for Medical Science	-0.034	0.142	0.031	0.813	
	Physics for Medical Science	0.417	0.132	0.426	0.002*	0.181
Biostatistics	Statistics for Medical Science	0.525	0.123	0.377	<0.0001*	0.142

* Significant difference at $\alpha = 0.05$

Discussion

To improve the quality of undergraduate biomedical science education in dental curriculum, it requires a deep understanding of approaches or factors that lead to student success and enhanced learning. Prerequisites are standard in college curricula and establish the preconditions and serve as a measure of preparedness for subsequent course enrollment. As such, valid prerequisite courses should increase the likelihood of success in target courses. For the current study we validate the prerequisite basic science courses in the first year dental curriculum. Three measures were examined: grades earned in courses, correlation between grades in target courses and its prerequisite courses, and a predictor of success in a target course. Data analysis revealed the variable positive correlation of the student success between 7 prerequisites and their target biomedical science courses.

We further evaluated whether the prerequisites could be the predictors of success in a target course. Data showed strong predictors of two prerequisites; the grade in Organic Chemistry was a significant predictor of successful in Biochemistry and Biochemistry laboratory ($p < 0.001$) and Biostatistics was a significant predictor of successful in Statistics for Medical Science Biostatistics ($p < 0.001$). It is not surprising that students who are successful in prerequisite courses might be expected to be success in upper-level courses. Reports have been shown that a student is highly unlikely to succeed in the course unless the student has met the proposed prerequisite. McCoy and Pierce reported that students without the prerequisites had only a 53% likelihood of earning grade of C or better in the upper-level courses [4]. Enforcing prerequisites decreased the failure rate by 18% and the withdrawal rate by 21%.

However, we found subtle correlations between prerequisites and their target courses and the conflicting results in the particular set of the prerequisites. Process of Life was a predictor of the target courses, Introduction to Genetics, while Essential Biology was not. Physics for Medical Science was a predictor of the target courses, Physical Principles in Life Science and Dentistry, while General Physic Laboratory and Basic Physics for Medical Science were not. The disconnection between established course prerequisites and the genuine value they have in student performance should be further evaluated. Several studies have been reported about the value of prerequisites. For example, Balla et al. found that the basic anatomy knowledge did not positively correlate with the ability of medical students to perform effective clinical diagnoses [5]. Another example is the finding that the grades in a research course of nursing students did not strongly correlate with their grades in the prerequisite statistic course [6]. Recently, Wright et al. found no statistically significant differences between average biochemistry grades between students with or without the organic chemistry prerequisite [7].

At Mahidol University, Faculty of Sciences is responsible to teach all prerequisite courses in first year students, while Faculty of Dentistry teaches all the biomedical and dental science courses. Therefore, teaching and learning methods to enhance learning in different classrooms may somehow impact student success. These also include the class format, the size of the class, the format of assessment, and the learning experiences. Besides grade earned, various factors such as, teaching style, gender [8, 9], ethnicity [10], entrance test scores, motivation, confidence, etc. can also impact student performance with unequal significance. In addition, the value of prerequisites may be more related to history, convenience, selectivity or course credits revenues. Other possible predictors should be further investigated.

The findings that some prerequisite courses were not predictors of the target courses also suggested the requirement of the content review that identifies the necessary and appropriate body of knowledge or skills students need to possess prior to enrolling in a course. Beyond content review, a number of studies have focused on understanding the factors that lead to student success and enhance student learning. In addition to enforced course perquisites, the students' awareness of the prerequisite and understanding of the learning outcomes that occur in the prerequisite courses will help the instructors ensure that the students are adequately prepared for their class. Otherwise instructors of target course might alter their course content, pace, or other ways. The study of Humphrey et al. found that having not completed basic science courses in the undergraduate preparation did not significantly affect dental students' performance neither on coursework nor on standardized board exams [3]. Intelligent and motivation is the key for their success in dental school.

There were several limitations with this study. Due to our relative small sample size, large outcome differences may not be identified as statistically significant difference. Gender and ethnicity were not analyzed in our study due to group proportional of our small sample size. Other academic factors and non-academic variables that may impact student success were not addressed in this study. The variation of curriculum among dental schools in Thailand makes our results less comparable to others. Although our results are not necessarily applicable to all dental curricula, they will help to determine the significance of basic science coursework as a prerequisite for the upper-level biomedical science courses. Due to evolving and changing undergraduate medical and dental curricula raise concerns about decrease of the basic science courses or be part of the core curriculum. In Europe and USA, physics, chemistry and biology are recommended as a prerequisite to entering medical and dental school. However, recently the study of Lynch et al. found that university basic sciences were more predictive than school sciences in undergraduate medical performance [11].

The results are encouraging for our dental program. This study provides guidance related to the impact of prerequisites on the performance of upper-level courses and support for retaining the current prerequisites for the target courses. In setting up prerequisites for upper level course, it is assumed that content validity have examined and tested. This is the first step in validating the coursework required for prerequisites in the dental curriculum. Similar studies should be done for other courses in term of the relationship between prerequisites and their upper-level courses. This is in part because certain course prerequisites do not appear to have any content validity. Certain variables like prerequisites need to be tested to validate the total coursework required. There must be adequate and sufficient evidence before any changes of the current curriculum regarding the assignment of courses to be prerequisites of upper-level or subsequent courses. In addition, some courses could would be reconsidered to assign as co-requisites which are not required for student to pass the course, just only attend/or register. More similar study would shed light on which courses are prerequisites and which are only co-requisites. This information would greatly help dental school to put together more efficient curricula.

Conclusion

For Mahidol dental students, final grades in some prerequisite basic science courses of the first year can significantly predict the success of the target biomedical science courses of the second year. Organic chemistry was noted to be the most significant prerequisite as a predictor for Biochemistry.

Funding: None

Competing interest: None

Ethical approval: The Institutional Review Board of the Faculty of Dentistry / Faculty of Pharmacy, Mahidol University COE. No. MU-DT/PY-IRB 2016/016.0308

References

1. American Dental Association. Clock hours of instruction by teaching area: 1999/2000 survey of predoctoral dental education, Vol 4. Chicago: American Dental Association, 2001.
2. Formicola AJ. Preprofessional preparation for the basic science curriculum. J Dent Educ 1986; 50: 458-61.
3. Humphrey SP, Mathews RE, Kaplan AL, Beeman CS. Undergraduate basic science preparation for dental school. J Dent Educ 2002; 66: 1252-1259.
4. McCoy and Pierce. The Function of Course Prerequisites in Biology. actionbioscience. 2004.
5. Balla JI, Biggs JB, Gibson M, Chang AM. The application of basic science concepts to clinical problem-solving. Med Educ. 1990; 24: 137-47.
6. Grace JT, D'Aoust R. Evidence-based program requirements: evaluation of statistics as a required course. Nurse Educ Perspect 2006; 27: 28-33.
7. Wright R, Cortner S, Winkel A. Minimal impact of organic chemistry prerequisite on student performance in introductory biochemistry. CBE Life Sci Educ 2009; 8: 44-54.
8. Turner RC, Lindsay HA. Gender differences in cognitive and noncognitive factors related to achievement in organic chemistry. J Chem Educ 2003; 80: 563-68.
9. Creech LR, Sweeder RD. Analysis of student performance in large-enrollment life science courses. CBE Life Sci Educ. 2012; 11: 386-391.
10. Seymour E, Hewitt NM. Talking about leaving: Why undergraduates leave the sciences. 1997. Boulder CO: Westview Press.
11. Lynch C, Grant T, McLoughlin P, Last J. The relevance of basic sciences in undergraduate medical education. Ir J Med Sci. 2016; 185: 195-201.