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Chemistry courses as the turning point for premedical students

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Abstract Previous research has documented that negative experiences in chemistry courses are a major factor that discourages many students from continuing in premedical studies. This adverse impact affects women and students from under-represented minority (URM) groups disproportionately. To determine if chemistry courses have a similar effect at a large public university, we surveyed 1,036 students from three entering cohorts at the University of California, Berkeley. We surveyed students at the beginning of their first year at the university and again at the end of their second year. All subjects had indicated an interest in premedical studies at the time they entered the university. We conducted follow-up interviews with a stratified sub-set of 63 survey respondents to explore the factors that affected their level of interest in premedical studies. Using a 10-point scale, we found that the strength of interest in premedical studies declined for all racial/ethnic groups. In the follow-up interviews, students identified chemistry courses as the principal factor contributing to their reported loss of interest. URM students especially often stated that chemistry courses caused them to abandon their hopes of becoming a physician. Consistent with reports over more than 50 years, it appears that undergraduate courses in chemistry have the effect of discouraging otherwise qualified students, as reflected in their admission to one of the most highly selective public universities in the US, from continuing in premedical studies, especially in the case of URM students. Reassessment of this role for chemistry courses may be overdue.

Keywords Chemistry · Diversity · Ethnicity · Medical education · Minorities · Premedical education · Science education · Race

Data presented in this paper will also be included in a forthcoming book: *Questioning the Premedical Paradigm—Enhancing Diversity in the Medical Profession a Century After the Flexner Report*, by Donald A. Barr. Johns Hopkins University Press, estimated release in 2010.

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Introduction

In an earlier study we reported that, among first-year students who enter Stanford University with an interest in becoming a physician, two groups are more likely to lose interest in continuing premedical studies: women and students from underrepresented racial and ethnic minority groups (URM; Barr et al. 2008). In follow-up interviews, these students reported premedical science courses, principally chemistry, as the main factor discouraging their continued premedical interest.

Other reports have also identified chemistry courses as a principal factor discouraging premedical interest among gifted URM students who had participated in a high school science enrichment program (Thurmond and Cregler 1999) and among students at a liberal arts college (Lovecchio and Dundes 2002). A number of authors have questioned the continuing role chemistry courses play in thinning the undergraduate cohort of premedical students (Emanuel 2006; Dienstag 2008).

The question arises as to whether the continuing adverse impact of chemistry courses on the premedical aspirations of college students is widespread among academic institutions, or alternatively whether it is institution specific. To address this question we replicated our earlier research, surveying students at the University of California, Berkeley. If chemistry courses were to have the same adverse impact at a large public university such as Berkeley as they do at a smaller private university such as Stanford, the need to reassess the role of chemistry courses in the premedical curriculum would become more pressing.

Methodology

The methodology we used at Berkeley differs in a number of ways from the methodology of our original study (Barr et al. 2008). While Stanford gathers information on future career plans from all incoming students, at the time of our study Berkeley did not. Accordingly we sent an initial e-mail to every incoming first-year student at Berkeley, asking the student whether s/he is considering a career in medicine following graduation. Those students who responded that they were considering medicine were asked to link to a website at which our survey was explained and informed consent for participation obtained. Respondents were then asked: "Please choose a whole number between 1 and 10 from the Interest Scale which best describes your current interest in being premed." Respondents were shown a previously validated 10-point Likert scale of interest with (10) labeled as "So committed to premed that nothing can stop me;" (7) labeled as "Probably will be premed;" (3) labeled as "Probably will not be premed;" and (1) labeled as "Absolutely no interest whatsoever in premed."

We re-contacted responding students at the end of their second year at the university, again asking them to rate their current level of interest on the 10-point scale. We then computed mean responses for each of the five principal racial/ethnic groups at both time periods (beginning of the first year, end of the second year), and compared the change in level of interest for these groups.

At Stanford, when a student responded to any of the surveys, the computer server housing the survey was able to record that student's unique identifier. In this way we were able to link responses at the two time periods for individual students. For Berkeley students the computer server was not able to obtain a unique identifier for each survey respondent. Accordingly in reporting our Berkeley data, we were unable to link responses for individual students. We thus are able only to compare changes over time in cohort mean responses rather than individual

students' responses. We report data on first-year students who entered Berkeley in the fall of 2003, 2004, and 2005. Of these three cohorts, we were able to obtain data about the level of interest at the end of their second year for the first two cohorts.

As a follow-up to the surveys, we conducted one-on-one interviews with 63 of the responding students, administered between the end of the subject's second and fourth years. We divided respondents into two groups, URM and non-URM, and randomly selected students from each group for interview. In doing so we over-sampled URM students, getting a final interview sample of 29 URM students and 34 non-URM students. As we did in our study of Stanford students, we first asked students which factors had affected their level of interest in premedical studies, and then asked them to identify any specific courses that had discouraged that interest. Two coders reviewed all interview responses to assure consistency in coding.

Results

Survey responses

A total of 1,036 Berkeley students responded to our survey at the beginning of their first year. Of these initial respondents, 589 also responded at the end of their second year (57%). The smaller number of second-year responders reflects a combination of one more first-year cohort than second-year cohort being included in the study, in addition to a lower response rate to the second-year survey than the initial survey. The mean level of interest in pursuing premedical studies at these two times for each of the five principal racial/ethnic groups is shown in Table 1. In the Table we also compare the interest level of these Berkeley students with that of the 362 Stanford students reported in our earlier study (Barr et al. 2008), recalling that the Stanford data included only those students who responded both as first-year and as second-year students. While the data from the two universities are thus not directly comparable, they nonetheless allow us to determine if the pattern of decline in interest seen at Stanford is also seen at Berkeley.

While premedical students at Berkeley and Stanford generally start their first year with about the same level of interest, the decline in that interest is quite a bit steeper at Berkeley. Native American students at both Berkeley (loss of 3.09 points) and Stanford (loss of 1.64 points) report the largest decline of all the groups. White (loss of 2.98 points), Asian (loss of 2.27 points), and Latino (loss of 2.31 points) students at Berkeley lose more interest than White (loss of 1.05 points), Asian (loss of 0.37 points), and Latino (loss of 1.32 points) students at Stanford.

African American students at Berkeley (loss of 1.36 points) and at Stanford (loss of 1.44 points) have a similar level of decline. However, while African American students at Stanford have the second-largest decline among all racial/ethnic groups, at Berkeley they have the smallest decline and end their second year with the greatest interest in continuing premedical studies of all the racial/ethnic groups.

Examining overlap in the 95 percent confidence intervals reported in Table 1, we see that among Berkeley students, the observed decline between the first and second year is statistically significant ($P < 0.05$) for the White, Asian, and Latino groups. Among the Stanford students, only the decline among White students reaches this level of statistical significance. However, we must note that the small sample size for the African American and Native American groups at both universities and for the Latino group at Stanford made it less likely that the observed differences would attain statistical significance.

Table 1 Interest in premedical studies at the beginning of the first year and end of the second year, by racial/ethnic group

Racial or ethnic group	Berkeley			Stanford			Change in level of interest
	Beginning of first year	End of second year	Change in level of interest	Beginning of first year	End of second year	Change in level of interest	
White	7.02 (6.77–7.27) <i>n</i> = 224	4.04 (3.54–4.53) <i>n</i> = 166	–2.98	6.71 (6.43–7.00) <i>n</i> = 142	5.66 (5.16–6.17) <i>n</i> = 142	–1.05	
Asian	7.07 (6.93–7.21) <i>n</i> = 667	4.80 (4.48–5.12) <i>n</i> = 340	–2.27	7.27 (7.00–7.55) <i>n</i> = 136	6.90 (6.46–7.35) <i>n</i> = 136	–0.37	
African American	7.36 (6.68–7.49) <i>n</i> = 36	6.00 (4.55–7.45) <i>n</i> = 22	–1.36	7.25 (6.63–7.87) <i>n</i> = 32	5.81 (4.82–6.81) <i>n</i> = 32	–1.44	
Latino	7.31 (6.94–7.69) <i>n</i> = 102	5.00 (4.10–5.90) <i>n</i> = 56	–2.31	7.49 (6.94–8.04) <i>n</i> = 41	6.17 (5.11–7.24) <i>n</i> = 41	–1.32	
Native American	6.29 (4.04–8.53) <i>n</i> = 7	3.20 (0.00–6.86) <i>n</i> = 5	–3.09	8.09 (7.17–9.01) <i>n</i> = 11	6.45 (4.24–8.67) <i>n</i> = 11	–1.64	

Data shows mean (95% CI)

Interview responses

As was the case at Stanford, Berkeley students identified “courses I have taken” most often as contributing to the change in their level of interest in premedical studies, mentioned by 41% of subjects. Students’ responses to the question, “Were there any specific courses at Berkeley that discouraged your interest in medicine?” are shown in Table 2.

As shown on the bottom section of the Table, 28 of 29 URM students (97%) mentioned at least one course that discouraged their interest in medicine. Many of these students mentioned more than one course. By contrast, 22 of the 34 non-URM students (65%) mentioned at least one course as discouraging them.

For those students mentioning more than one course, the interviewer followed up with a question asking the student to identify the one course that was the most discouraging. Of the 28 URM students mentioning at least one course, chemistry was cited as the most discouraging course by 20 (71%). Of the 22 non-URM students mentioning at least one course, chemistry was cited as the most discouraging course by 12 (55%). For both groups of students, chemistry was cited *between four and five times more often* than the next courses, biology and math. It thus seems that chemistry courses are the factor that most discourages Berkeley students from continuing in premedical studies.

While more than one-third of the non-URM students responded that none of their courses discouraged their interest in premedical studies, only one of the 29 URM students reported this absence of discouraging courses. It appears that chemistry and the other premedical courses at Berkeley are more discouraging for URM students than for non-URM students.

Table 2 List of courses that discouraged students’ interest in premedical studies

Course	URM students (<i>n</i> = 29)	Non-URM students (<i>n</i> = 34)
Most discouraging course		
Chemistry (all courses)	20	12
Biology	3	3
Math	4	2
Physics	1	3
IDS	0	1
Language courses	0	1
No course discouraged me	1	12
List of all discouraging courses reported		
Organic chemistry	11	12
Inorganic chemistry	11	4
Chemistry-unspecified	4	2
Chemistry—total	26	17
Biology	9	9
Math	11	2
Physics	1	5
IDS	0	1
Language courses	0	1
No course discouraged me	1	12

We looked for any mention by the student during the interview of a course that was so discouraging that, as a result of having taken it, the student may have changed his or her aspiration regarding a career in medicine. We have excerpted below specific text that addresses this issue from our interviews with six of the URM students.

Subject 1—Latina female

Q: How would you compare your current level of interest in becoming a physician with the interest you had when you entered as a freshman?

A: I wanted to do it a lot freshmen year, but afterwards I stopped.

Q: What were the factors that led to the decrease in your level of interest?

A: I didn't think that I could do very well in the chemistry classes... I wanted to be pre-med when I first got here. But then after the first semester, I stopped... I think a lot of students get scared after Chem IA [inorganic chemistry].

Subject 2—Latina female

Q: What were the factors that led to the decrease in your level of interest?

A: Chemistry. [laughter] Yeah, just the level of competitiveness here... I'm sorry, but chemistry is just—having to take that much and study a lot it's just—I don't like doing that. So it's just like why do that?... I've heard many experiences after taking Chem 3 [organic chemistry]. This is just like the peak. You like it or you don't. This is the turnaround point.

Subject 3—African American female

Q: How would you compare your current level of interest in becoming a physician with the interest you had when you entered as a freshman?

A: It's changed a lot. Yeah, so. When I first came, I wanted to go into healthcare. And that's what I knew I wanted to do. But then when I started taking the classes, it changed.

Q: What were the factors that led to the decrease in your level of interest?

A: Mainly just the classes and the level of difficulty in the classes. I had to repeat Chem IA.

Subject 4—African American female

Q: Were there any specific courses that discouraged your interest in medicine?

A: I think having to drop Chem IA in the Spring of my first year made me question whether or not I could do it... I really didn't tell anyone because I didn't want to seem stupid. And then when I eventually had to drop it, I remember like I was hiding from certain people because I didn't want them to know. [laughter] ...So it was just a matter of me not wanting to feel dumb around other people.

Subject 5—African American female

Q: How would you compare your current level of interest in becoming a physician with the interest you had when you entered as a freshman?

A: Well, my first semester I was in Chem IA and calculus. And it was just like really, really big lectures and a lot of time. And I just felt like I wanted something that was smaller and more focused... A lot of people get scared either before or after O-chem and decide they don't like it [medicine] anymore.

Subject 6—Latina female

Q: Were there any specific courses that discouraged your interest in medicine?

A: Chem IA. Introduction to Chemistry or whatever. I took it twice. Um, well once I dropped after the 10th week mainly because on my part I felt that I didn't put enough effort. It just seemed like no matter how hard I tried, I would still probably do bad on the test and stuff like that... That's probably the class at Berkeley that discouraged me from being pre-med... My friends also felt discouraged... They dropped out of their pre-med pursuit cuz of Chem IA.

There is one aspect of our data that suggests a potential mitigation to the problem of loss of interest in premedical studies following negative experiences in the chemistry classroom. As shown in Table 1, both at Stanford and at Berkeley, African American students began and ended at about the same level of interest. However, the African American students at Stanford ended with the second lowest interest level among the various groups, while the African American students at Berkeley maintained the highest level of interest of any group.

The reason the African American students at Berkeley remained at a high level of interest relative to other Berkeley students may be reflected in the following excerpts taken from the interviews with three African American students. When asked if there were any people or programs at Berkeley that helped the student to maintain his or her interest in a medical career, these students responded:

I guess the people that would come the closest to that would be the people in BSP. [Biology Scholars Program] When I came to them Spring of last year telling them about my chem problems, they just sat me down and told me that... [it] doesn't mean my whole plans are gonna be thrown off track... If it wasn't for them, I don't know who I'd turn to.

Just knowing there's people at BSP who have made it... just kinda made me think that I could be there one day.

Well, the leaders of BSP... From BSP they tell us about research opportunities, and... like they go over what classes you need to take as well.

In response to low numbers of URM students choosing to major in the biological sciences (a common major for premedical students), in 1992 UC Berkeley established the Biology Scholars Program (BSP). With funding provided by the Howard Hughes Medical Institute, BSP had the goal of “promot[ing] the success of undergraduates from economic, gender, ethnic, and cultural groups historically underrepresented in the biological sciences” by providing “a continuum of resources available to help its members address critical transitions (e.g., making the high school-to-university academic and social adjustment, declaring a major, applying to graduate or professional school) throughout their undergraduate years” (Matsui et al. 2003). We found repeated evidence in the interview transcripts, with African American students as well as with students from other racial/ethnic groups, that BSP is viewed by these students as a crucially important bulwark of support as

they go through the demanding, and often discouraging, early premedical curriculum, especially the curriculum in chemistry.

Discussion

Early experiences in one or more chemistry courses appear to be a principal cause of the observed decline in interest in continuing premedical studies among students at both the University of California, Berkeley and Stanford University. The discouraging effects of chemistry courses appear to be felt more acutely by URM students at both campuses.

From the results of our interviews it appears that the adverse effects of chemistry courses experienced by many of the URM students lead directly to these students questioning their own ability to continue to pursue a medical career, and as a consequence dropping medicine as a possible career option.

Many of these students may have come from high schools that had relatively weak offerings in the sciences, placing these students at a disadvantage relative to students not from a URM group who may have attended a more privileged high school with stronger science preparation. In addition, a majority of these URM students at Berkeley are women and, as studies of elementary and secondary education have suggested (Seymour and Hewitt 1997), may have experienced additional disadvantage in their early science education. For these students, entering Berkeley with the hope of becoming a physician and then having a negative experience in a chemistry course is a major turning point in their professional life. In the words of two of the students whose interview text appears above:

I didn't think that I could do very well in the chemistry classes...I wanted to be pre-med when I first got here. But then after the first semester, I stopped.

I'm sorry, but chemistry is just... I don't like doing that...This is just like the peak. You like it or you don't. This is the turnaround point.

At the beginning of the twentieth century, medical education in the US became differentiated from that in the UK and parts of Europe, in that the educational sequence was split into separate phases at the undergraduate and medical school levels. Early courses in the sciences of chemistry, biology, and physics were assigned to the undergraduate curriculum. The most typical sequence of science courses in the US, adopted initially in 1905 (Bevan 1905) and still the norm today, expects first year students to take an introductory course in chemistry, with additional courses in biology and physics in the second year or later for those students successfully completing their first-year chemistry courses. This course sequence may partially explain why students identified courses in chemistry so much more often than those in biology or physics as having a discouraging effect on continued interest in pursuing a medical career. However, even for non-URM students, most of whom successfully complete their undergraduate science courses and subsequently move on to medical school, chemistry courses were substantially more likely to have a discouraging effect than other science courses. Thus there may be some unique aspect of the curriculum or pedagogy of chemistry that discourages most students from pursuing a medical career, but does so disproportionately for URM students.

In the responses of the interview subjects, some students indicated that they felt out of place in the chemistry classroom, while others referred to the difficulty they were having in meeting the work load and academic demands of chemistry. The question arises as to whether those students who are unable to attain the level of academic performance

expected in chemistry courses can reasonably expect to succeed in medical school. Studies from both the UK (McManus et al. 2005) and the US (Mitchell 1990) have documented a consistent association between performance in introductory courses such as chemistry and performance in the preclinical years of medical school. However, as concluded by Montague and Odds, “In general these studies have indicated that there is a positive correlation between performance in science A-level or equivalent examinations and performance in the early part of the medical course, but that this correlation decreases as students progress through the course” (Montague and Odds 1990, p. 151).

In 1953, a report issued by the national Survey of Medical Education titled *Preparation for Medical Education in the Liberal Arts Colleges*, observed that introductory science courses were often used at colleges and universities throughout the US to prevent students who do not do well in them from, “cherishing inappropriate professional ambitions too long” (Severinghaus et al. 1953, p. 11). The report went on to note that many students were “weeded out” in this manner as the result of, “an unduly tough attitude on the part of many chemistry teachers who claim with pride that only students of good ability who work very hard can get through their chemistry course.” The authors of report, representing a number of leading medical schools, spoke critically of the role chemistry courses had assumed in this “weeding” process: “...it is surely bad educational practice for one teacher, or one department, to act as a self-appointed obstacle. Administrators should see to it that this attitude is not permitted to develop or continue” (Severinghaus et al. 1953, p. 99).

At both private universities such as Stanford and public universities such as Berkeley, this weeding process continues and falls disproportionately on URM students, many of whom are the very students the University of California system of medical education is expected to train as physicians to meet the health manpower needs of our increasingly diverse state (Grumbach et al. 2008). It appears that the time is right to undertake a fundamental reassessment of the historical role chemistry courses have played in the premedical curriculum at colleges and universities throughout the country.

Repeated studies in the US have shown that undergraduate performance in premedical sciences such as chemistry, while predicting performance in the preclinical phase of medical education, has little if any power to predict the subsequent clinical skills of medical students, acquired in the final years of medical school or the early years of residency training (Veloski et al. 2000; Donnon et al. 2007; Basco et al. 2000; Violato and Donnon 2005). As described by Jules Dienstag of Harvard University, “the topics covered in many courses in chemistry, physics, mathematics, and even biology are so removed from human biologic principles that they offer little value to the premedical—or advanced human biology—student” (Dienstag 2008, p. 221).

The sequence of science courses required for admission to US medical schools, first defined in 1905 by the Council on Medical Education of the American Medical Association, has changed little since that time. One must question whether, after more than 100 years, there might be more innovative ways of organizing the teaching of premedical science. In many universities in the UK and Europe, the science preparation for medical training has been streamlined, focusing principally on those aspects of chemical knowledge truly necessary to succeed in clinical training and as a physician. Many educators in the US have suggested that premedical science training within the undergraduate university could be simplified and made more efficient in preparing students for medical school.

Dienstag goes on to argue that, “premedical requirements for rigid, 1-to-2-year, discipline-specific science courses should give way to more creative and innovative courses that span and unite disciplines...Medical schools should stimulate colleges to innovate, and premedical students should demand science courses that prepare them directly and

efficiently for the advanced study of biology. Premedical science should never have become a ‘trial by fire.’” (Dienstag 2008, p. 223).

The “trial by fire” of the first-year chemistry classroom is overdue for reform. That reform will likely involve new pedagogical approaches to the teaching of chemistry as but one of several contributors to our knowledge of human biology, rather than a course whose purpose is to “weed out” otherwise qualified students who hope to become physicians.

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