CBE—Life Sciences Education
Vol. 6, 316–331, Winter 2007

Article

Identifying Future Scientists: Predicting Persistence into Research Training

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Submitted April 9, 2007; Revised June 12, 2007; Accepted July 6, 2007
Monitoring Editor: Elizabeth Armstrong

This study used semistructured interviews and grounded theory to look for characteristics among college undergraduates that predicted persistence into Ph.D. and M.D./Ph.D. training. Participants in the summer undergraduate and postbaccalaureate research programs at the Mayo Clinic College of Medicine were interviewed at the start, near the end, and 8–12 months after their research experience. Of more than 200 themes considered, five characteristics predicted those students who went on to Ph.D. and M.D./Ph.D. training or to M.D. training intending to do research: 1) Curiosity to discover the unknown, 2) Enjoyment of problem solving, 3) A high level of independence, 4) The desire to help others indirectly through research, and 5) A flexible, minimally structured approach to the future. Web-based surveys with different students confirmed the high frequency of curiosity and/or problem solving as the primary reason students planned research careers. No evidence was found for differences among men, women, and minority and nonminority students. Although these results seem logical compared with successful scientists, their constancy, predictive capabilities, and sharp contrast to students who chose clinical medicine were striking. These results provide important insights into selection and motivation of potential biomedical scientists and the early experiences that will motivate them toward research careers.

INTRODUCTION

Many children start out in grade school and high school "liking science," but relatively few persist on through college into science-related careers. Even smaller is the number who choose to go from learning about science to discovering new knowledge as a scientist. Of the published studies on the persistence of students in science, almost all have examined student progression through science, engineering, and math undergraduate degrees, often focused on those who leave these majors (cf. Levin and Wyckoff, 1988; Carter and Brickhouse, 1989; Treisman, 1992; Seymour and Hewitt, 1997). The unanimous conclusion from all of these and other studies is that by far the greatest reasons students leave science, math, and engineering majors in college relate to the nature and quality of science teaching and the "culture" within the sciences. Little evidence was found for a lack of ability in science and math in a majority of those who chose to leave. In the most comprehensive study, Seymour and Hewitt (1997) found that both switchers and nonswitchers perceived the quality of science teaching as poor and a cutthroat competitive atmosphere in science classes. Faculty often fostered this atmosphere through their belief that science was difficult and, therefore, early science classes should be used to "weed-out" those of lower ability. In reality, this atmosphere did little to differentiate students by ability but rather by their willingness to tolerate the atmosphere, which had a disproportionately negative impact on women and minorities.

One of the most successful programs to retain minority students in science majors and propel them into graduate training is the Meyerhoff Scholars Program of the University of Maryland Baltimore County. A detailed study of the program revealed the many facets that supported its success (Maton *et al.*, 2000). Some of these factors were as follows: the learning community of which the students became part,

DOI: 10.1187/cbe.07–04–0020
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financial support, mentors, peer tutoring, and academic counseling. However, one of the highest-rated experiences for the Meyerhoff students was the summer research internship. These internships were designed as hands-on meaningful experiences that would give students a realistic look at what scientists do, and for many confirmed their desire to pursue the Ph.D. As one student said in this study of Meyerhoff scholars "[Most valuable has been] the thinking process, how you go about trying to solve a problem, and all the different techniques you can use to get around problems." Although a highly successful program, the Meyerhoff study did not report any systematic comparisons between those students who went on to graduate versus medical schools, or those who did not stay in a science major.

The studies highlighted above have revealed a great deal about what pushes students away from and toward science, math, and engineering undergraduate majors. However, very few if any studies have attempted to systematically investigate those who do persist in science, especially the factors that draw the small fraction of students who go on to advanced research training. Given the ongoing discussion and debate on how to maintain the U.S. position in the global science market, knowing what leads students to stay in science and, especially, pursue research careers is critically important. Because so little was known about this topic, this study purposefully started from the assumption that we had no idea as to the deciding factors. Thus, open-ended, semistructured interviews of students were used to ask the following: What compels students to persist into Ph.D. and M.D./Ph.D. training, specifically with the intent of doing research? What is it that separates these individuals from those who choose to *use* science, such as in medicine? Are there differences in what compels underrepresented minority students to pursue research careers? Are there differences between women and men? Thus, this is a study of the themes that reveal the decision-making of students who have persisted in science, math, and engineering through college toward biomedical careers.

MATERIALS AND METHODS

Population of the Study

The National Institute of General Medical Sciences (NIGMS) of the National Institutes of Health (NIH) has played the largest role of all national agencies to support and promote programs to encourage underrepresented minority groups to pursue biomedical research careers. Details of the NIGMS-sponsored programs can be found at http://www.nigms.nih.gov/minority/. In 1996, a new NIGMS program called the Initiative for Minority Student Development (IMSD) was created, through which any academic institution, even if it did not have exceptionally high minority enrollments, could initiate and seek funding for programs to increase the number of minority biomedical scientists. A new requirement was added, however, that any such grant had to include a detailed plan to evaluate the effectiveness of the program. As a part of the Mayo Clinic IMSD, research was initiated to study the decision-making processes of college students in the Mayo IMSD, as well as a companion Summer Undergraduate Research Fellowship (SURF) program open to both minority and nonminority students. Most of the students were deciding between clinical medicine and research careers.

The first students asked to participate in the study were those who applied to and were accepted into the SURF program at the Mayo Clinic College of Medicine in 1996. This highly competitive program engages rising juniors and seniors in authentic biomedical research for 10 weeks during the summer. The program attracts between 700 and 1200 applicants annually from around the United States. Between 60 and 90 students are selected each year. Students were provided a stipend of $3000 for the 10 weeks from which they paid their own transportation, housing, and other expenses. The application process is typical of most summer research programs, requiring a current transcript, two letters of recommendation from previous research mentors or other faculty, and a personal statement covering their reason for applying to the program and future plans. IMSD undergraduate students were drawn from the SURF applicant pool and were fully integrated into all of the activities of the SURF program. Individual faculty selected students for their labs from the applicant pool using whatever criteria they felt appropriate. Some faculty focused on academic performance, although most selected students had a GPA of 3.5 or higher, some focused on students having prior research experience, some emphasized letters of reference, and some weighed personal statements highly. Although certain faculty looked for experienced students who could be very productive in the lab, others preferred to give younger or inexperienced students a first chance. Thus, the population in this study can be characterized as academically successful science majors with an espoused interest in graduate or medical training, with quite varied prior experiences.

One goal of the SURF and IMSD programs was to attract and accept underrepresented minorities. Based on this goal, 25–35% of the accepted students were African American, Hispanic, or Native Americans. In addition to this ethnic diversity, the population was highly diverse in terms of state of residence, school, and type of school attended (e.g., liberal arts or research intensive; public or private).

The second group invited to be in the study were participants in the postbaccalaureate research program of the Mayo Clinic IMSD. Individuals in this program had recently graduated from college and were spending 1 or 2 years doing research before entering Ph.D., M.D., or M.D./Ph.D. programs. Most of these students graduated from college unsure of their future career decisions and/or with some insufficiency in their prior background to be competitive for graduate or medical programs. They were provided a salary of $21,000 and worked full time as research assistants while taking up to one graduate level course per quarter. The pool of applicants for this program was much smaller than SURF, 30–50 applicants for six to eight new positions each year, and almost all were from underrepresented minority groups. A concerted effort was made to identify those applicants most likely to persist into Ph.D. and M.D./Ph.D. training. However, no more than 50% of the students who joined this program actually did choose to enter Ph.D. or M.D./Ph.D. programs; the majority of the others entered M.D. programs.

During the years 1997–2000, a total of 109 students were interviewed as part of the overall study (approximately 20% of the total students doing summer research during this time). Analysis of interviews began with the first cohort of students in 1997, before any of them had actually graduated and gone on to graduate or medical training. Over the next several years, as initial themes emerged and students entered advanced training, a stratified random sample of 26 students was chosen from the 109 for in-depth analysis. All except one were undergraduates who had done summer research at Mayo. The other student joined the postbaccalaureate research program immediately after graduation from college. This subpopulation was chosen to provide broad representation across gender, ethnicity, and choice of advanced training. Table 1 provides the demographic profiles of the subpopulation of students upon which this report is based. Except for the oversampling of underrepresented minority students, this subgroup is representative of SURF students. Of the minority students, two came from historically black colleges and universities (HBCU) and one came from a Hispanic-serving institution. Thus, the minority students are more representative of those at predominantly majority institutions than minority-serving institutions.

Table 1. Demographics of initial 26 student study population

	No.
Gender	
Male	10
Female	16
Years of college completed	
Two	12
Three	13
Four (B.A.)	1
Ethnicity	
White	11
African American	9
Hispanic	4
Native American	1
Asian	1
GPA	
Mean	3.69
Median	3.72
Range	2.98–4.00
College/university type	
Public	11
Private	15
College/university category	
Baccalaureate college	6
Master's	5
Doctoral: high research	4
Doctoral: very high research	11

Study Design

Because so little was known about how and why students choose to pursue graduate school and research careers, we chose to use individual interviews and open-ended questions that explored students' realities (Seidman, 1998). These questions probed past experiences, the basis for their interest in science, influential people and events from their past, and their motivation, interests, and aspirations for the future. Students were encouraged to simply "tell their story" of past experiences and current plans.

Individuals invited to participate were given a brief summary of the study with full freedom to participate or not. Those who agreed to participate (all but one person) were provided with a more detailed description of the study as part of a written informed consent document. Students were assured their comments would remain completely confidential and would in no way influence recommendations or future applications to Mayo Clinical College of Medicine academic programs. Students could withdraw from the study at any time, and one person declined to continue after the second interview. Additionally, they were given the opportunity to review the transcripts of their interviews for accuracy if they wished, but none chose to do so. The study was submitted to and approved by the Mayo Clinic Institutional Review Board as a minimal risk study.

Each student participated in three audiotaped interviews during the study. The first was within 1–3 days of the beginning of the program in order to understand their starting point. It was the longest, lasting 45 min to an hour or more. The length of the interview was controlled primarily by the interest of the students in telling their stories; most were very eager to tell who they were and how they had arrived at their current thinking. The second interview was conducted during the last week of their summer research or very close to the time they finished the program. This interview was shorter, often because students were busy finishing projects, and it probed more the changes they had experienced, rather than their life stories. The third interview was usually conducted by phone ~8–12 months after they had left the Mayo Clinic. The goal of this interview, which largely used the same questions as the second interview, was to determine whether their thinking had changed from the time they left, any new insights or ideas they had achieved, and updated plans for the future. This interview tended to last ~30 min. (See Supplemental Material I for interview questions.)

The authors trained and supervised the Program Assistant for the IMSD, who was an African American woman with a liberal arts, nonscience background, to conduct student interviews. She did not participate in analysis of the interviews to maintain her objectivity during them. Because she did not evaluate student performance or write recommendations, it was believed students would be more relaxed and less guarded during the interviews. Students were given the questions approximately a day in advance of their interviews because the goal was thoughtful reflection rather than first reactions. The interviewer was trained to listen for evidence of students' goals, perceptions of science, and self-perceptions and then to encourage students to expand their responses to find underlying reasoning. During the second and third interviews, students were asked to reflect on important observations or insights from previous interviews.

Transcript Analysis

The audiotapes were transcribed and independently analyzed by the authors using Grounded Theory (Strauss and Corbin, 1990). The goal was to identify and categorize events, experiences, perceptions, and personal qualities that appeared to be important to the individual student. After the authors had independently analyzed the transcripts, major themes were identified and compared. Any disagreements were discussed, and tapes were listened to until agreement was reached. Additional interviews were then analyzed using preliminary theme structures but always looking for themes that might not have been evident in interviews analyzed earlier. If new themes were uncovered, previously analyzed interviews were reexamined to see whether those themes were present, not initially observed, or absent. Through this reiterative process, eventually no new themes emerged after analyzing the interviews of the first 26 students. This method for collection and analysis of interview data in a similar context has recently been described in detail (McGee and DeLong, 2007).

When the interviews were first conducted and analyzed, the students were still in college and/or had not firmly committed to entering graduate or medical school. Thus, the analysis was conducted "blind" to student outcomes. As interviews and analysis continued over several years, the career path choices of students became evident. Using constant comparative analysis (Glaser, 1992), the themes found in the interviews were compared between those students who chose biomedical research or other advanced training.

Institutional Context

Although the study was designed to uncover student characteristics formed by past experiences, it is important to understand the context in which the students were interviewed as it might influence their answers to questions. The Mayo Clinic is known mostly as a premier institution of clinical medicine. However, it is also a freestanding, fully accredited, degree-granting institution: the Mayo Clinic College of Medicine. Mayo Medical School provides M.D. training and Mayo Graduate School Ph.D. training in several biomedical disciplines, and together they provide an integrated M.D./Ph.D. program. Additionally, the School of Health-Related Sciences provides training in a number of allied health disciplines. With an annual research budget of more than $350 million from public and private sources, Mayo Clinic is also highly recognized for its basic and clinical research.

The atmosphere and approach to medicine and research at Mayo can be best described as collegial, professional, collaborative, and supportive. Research investigators all receive institutional research budgets as a basis for seeking additional outside funding. Thus, the

atmosphere for research tends to be less competitive than many biomedical research institutions. At the time of the study, there were approximately 100 independent research groups; virtually all collaborated actively with other research groups at Mayo and elsewhere. In general, the technology for research is provided in research core facilities to which everyone had access, thus allowing students, postdocs, and investigators broad access to modern research resources.

In 1991, a new Office of Minority Student Affairs was created to expand and incorporate diversity activities across the Mayo Clinic schools. The office was integrated across the schools rather than separate from them, which allowed for close coordination of the IMSD and SURF programs. The Office provided a sense of community for minority students both in degree programs and various shorter internships and fellowships. The Office was also responsible for bringing Mayo programs to the attention of minority students, most of whom were unaware of the Mayo Clinic either as a clinical or educational institution.

RESULTS

The interview questions and interviewer approach were designed to allow students to relate the important events and decision points that led them to be part of the SURF or postbaccalaureate research programs at Mayo and to their future plans (Seidman, 1998). Several factors might have caused students to be reluctant to talk or reveal decision processes. First, they might not feel comfortable talking about important life events with someone they had never met or hardly knew. Second, they could be concerned that being too honest might impact either their experience at Mayo or subsequent applications to Mayo programs. Third, they might not want to be bothered with taking the time. None of these concerns appeared in any interviews. To the contrary, the vast majority of students was highly talkative, gave no indication of hesitation in talking about themselves, and often talked much longer than they or we expected. A number of students openly thanked the interviewer for taking the time to ask about and be genuinely interested in their stories. The interviews were able to take on the context of an engaged conversation more than a formal interview. This is not to say that all students had complete or clear understanding about themselves, the importance of past events, or where they were headed. But they seemed genuinely open to sharing their perceptions at the time of the interviews.

The degree to which students had thought about past experiences and their rationale for being in the research programs varied substantially. For some, their response was almost like opening a book and telling a story that had already been written. They had thought through, interpreted, and made conscious decisions based on their analysis. Others had less insight into themselves and what had influenced them, but most of these individuals were able to articulate and interpret their experiences as the interviewer probed their answers.

Using open-ended questions the entrance interview consciously approached perceptions of research and career plans indirectly to minimize the possibility that students might try to provide answers they thought the interviewer might want to hear. By establishing rapport using these questions, we believe students became comfortable with honestly reporting and responding. Keeping the interviewer and interviews very separate from decision-makers in the program also alleviated concerns about saying the wrong thing. Additional evidence for their comfort with the interviews was the fact that none of the students declined to do the exit interview and only one declined to do the follow-up interview. Unlike difficulties getting students to fill out paper and Internet surveys, students were very happy to continue in the study.

When the analysis began, those being interviewed were still in college and their choices for advanced education and potential career paths were unknown. Thus, the analysis was uninformed with respect to this outcome. As time went on, the postbaccalaureate paths of the 26 individuals became known and are provided in Table 2. All but two of the students went on to M.D., Ph.D., or M.D./Ph.D. programs. One student who applied to medical school was not accepted. A short conversation with his parents revealed that he went into the work world. The other student chose to teach secondary school science. This high rate of success was consistent with all students from the SURF and postbaccalaureate programs. Thus, the initial study subsample is representative of the larger pool of Mayo SURF and postbaccalaureate students. Because all but one of the students went on to their preferred advanced education, student choice is being studied, not student success or failure at achieving a desired choice.

Once the students' career paths became known, the authors began looking for themes that either did not or did differentiate among the groups of students. The results section first describes those themes that did not differentiate career paths and second, those that did differentiate among those students who pursed the M.D., M.D./Ph.D., or Ph.D. A third section discusses the patterns found among students who either chose the M.D. with the clear intent to do research or initially entered M.D./Ph.D. programs but later dropped out to complete the M.D. degree only. The last section presents the analysis of data from a survey of SURF students that was based on the initial interview study results.

Themes That Did Not Differentiate Career Paths

Not unexpectedly, a great majority of the students talked about individuals who played critical roles in shaping and guiding their interests and their career directions. However, no patterns emerged that revealed differences between students who continued with research and those who chose other career options after graduating from college. Very few talked about parents or other family members, whereas many talked about events, teachers, research mentors, and

Table 2. Postbaccalaureate degree programs of study population

Initial graduate program or other plans	Number
Ph.D. (1 later changed to D.V.M.)	10
M.D./Ph.D. (2 later changed to M.D. only)	5
M.D. (3 with ongoing interests in research)	9
Business or teaching	2
Total subsample population	26

D.V.M., Doctor of Veterinary Medicine

other role models as having had profound impacts on their thinking. For those who had done research previously, their research advisors/mentors were often mentioned as being most important. Although a number of students talked about less-than-satisfactory experiences with teachers and mentors, most often those experiences did not redirect their goals, and sometimes these students talked about how they grew from the experience. Of course, those students whose negative experiences made them leave research are likely not in this sample because they would not have applied for the program.

There were two very common themes that emerged from the interviews and were evident across the groups but did not differentiate among them. The frequency with which they appeared gave an indication of how important they were to these students. The themes were self-confidence and action orientation.

Self-confidence. There were many examples of self-confidence throughout 22 of the 26 students' interviews. The excerpts below illustrate this characteristic. This was a group of students who 1) asked questions, 2) took intellectual risk, and/or 3) took a leadership role to fulfill a need. In all quotations, "S" refers to student and "I" refers to interviewer. Subject initials are coded rather than true initials to preserve confidentiality.

> S: So it got to the point where I had to stand up to this woman. It took me a while but I realized what have I got to lose? If somebody doesn't like me, they don't like me. If they find me a pest, they find me a pest. . . . But I want the answers and I'm not afraid to be told no. My feelings get hurt [and] maybe it's selfish, but I do want to better myself and if it takes pestering somebody or taking their time, it's a chance I'm going to take. And if they tell me no, I'll find another way to get the information. (A.J., M.D./Ph.D., Interview 1, lines 782–791)

> I: Now if I can backtrack a little bit, how did you end up going to this medical magnet in high school?
> S: Oh, because I was in junior high and I was taking Physical Science and they came to recruit in my school. And she was very nice, Miss Weinstein—I think she also has changed my life completely because she came in the classroom and they were just starting this medical magnet and it was the first year. It was a predominantly black school. I wanted to do it and my mom was like, "Don't you dare do it because it's a very bad neighborhood." But I said, "This is what I want." I said, "If I finish my freshman year here, I'm going to stay here for four years." I did. I graduated from that school. (V.M., Ph.D., Interview 1, lines 69–79)

Action Orientation. Nineteen of the 26 students talked about actively seeking out new experiences. In addition, there were many comments that illustrated how this group of students did not sit back waiting passively for something or someone to change the situation for them. The following excerpts illustrate how they did not walk away from new experiences but embraced them.

> S: It's a Rotary summer exchange. Even that was sort of scary for me to think about—to be gone for a month in some foreign land. In high school a lot of my friends studied abroad and had great times. By the time I was a freshman or sophomore in college I thought maybe I should give it a shot. . . .
> I: You just got back? Oh my.
> S: Actually it was sort of Saturday morning before I landed in Minneapolis about 1:30 in the morning. I was home for about 24 hours and then drove back here on Sunday. (G.T., Ph.D., Interview 1, lines 329–343)

> S: So [I] generated this list of summer programs and I applied to about five on the list and I got accepted to, I believe, three out of the five. And one was in Baltimore, Maryland, but I was in Baltimore last summer, . . . a neurosurgery preceptorship there, so I figured . . . and Mayo's world renowned. I've heard of it everywhere and when I got accepted, I was really excited. I really was. And I've never been to Minnesota, never been [to] the Midwest. So I thought I may as well broaden my horizons, spread my wings, and go somewhere new, 'cuz like I said, I was born in DC, I have family there and I would have loved to go but you know, I wanted to experience something different. That's why I came here. (W.D., M.D., Interview 1, lines 110–120)

> S: My biggest dream was to work at NASA. But then I had a science teacher who offered me to go to an interview in the _ School of Medicine where I am from . . . the city of _. And so I went to that interview with the idea of studying engineering. Well, I didn't do well in the interview. They chose another student from my school who wasn't very interested at all. I was very interested in the experience of research in the laboratory [that] was very new for me—completely new. But they chose this student and I got very frustrated because why she when she wasn't interested . . . and not me . . . that I was interested. So I called the director of the program. The program is called Minority . . . it's from the National Institute[s] of Health . . . Minority High School Students Research Apprentice Program. I called the director and I asked her to accept me as a volunteer to work. So fortunately, I got to work at the _ School of Medicine and Research during my high school and definitely that was the experience that changed my whole life . . . my whole career life. (M.Y., Ph.D., Interview 1, lines 26–46)

> I: When you say you started [the journal club] . . . You founded it?
> S: Yep and there's probably about 10–12 people in it right now. We've made posters. We have a vice president and people like that. Basically we try to meet every 2–3 weeks and use similar format. We hand out a journal article—it might be on Alzheimer's or something with cancer—we talk about Huntington's and all sorts of different diseases. In the past, I've usually been group leader and I think of questions and sometimes I go up there and explain things like the cell cycle and some parts of the article that are kind of basic but people might not know too much about. And then we kind of go off on that and talk about a few things. Basically I've picked a few people to try and lead it and see how they can do it—and I try to help them out with that. It's a real similar format to what we did at Mayo.
> I: What made you decide to do that at school?
> S: I knew there was a need here. It's kind of a smaller college. I figured the people who really want to go into medicine or to grad school should really have the

> opportunity to see what it's really like, to see what they're going to have to read and see what they should prepare for. (M.N., Ph.D., Interview 3, lines 54–73)

The themes of self-confidence and action orientation did not differentiate between groups of students; however, they were very consistent across the groups and indicated how these students viewed themselves and managed their journey to their chosen career paths.

Themes That Differentiated Degree Paths

As described in the student demographics (Table 2), all but two students went on to Ph.D., M.D., or M.D./Ph.D. training after graduation. During the analysis, a distinctive set of themes was found among a high fraction of students who went on to the Ph.D. or M.D./Ph.D. These themes were also found in a subset of those who chose M.D. programs, specifically those students who intended to do research with that degree. The themes were very different for students with little or no ongoing interest in research. The following were the five themes that differentiated students who persisted toward research: 1) curiosity to discover the unknown, 2) enjoyment of problem solving, 3) a high level of independence, 4) the desire to help others indirectly through research, and 5) a flexible, sometimes ill-defined approach to the future.

1. Curiosity to Discover the Unknown. Fifteen of the 18 students who started advanced training with the intent of doing research expressed a strong curiosity for finding out something new that had never been known or discovered before. One of the three who did not mention this idea dropped out of the Ph.D. program to pursue a D.V.M. after 1 year. By contrast, only one of the eight students who left college with no interest in doing research expressed an interest in discovering the unknown.

The following quotes illustrate the excitement students who persisted to the Ph.D. or M.D./Ph.D. expressed when they were asked about research. Students talked about being on the frontier, or on the cutting edge of research. They mentioned looking for something that others did not know or finding an answer to questions that have not been answered.

> I: What do you think will be the most fun about being here?
> S: Um, I think the most fun to me is going to be every day walking into the lab and knowing that this is the cutting edge of research. It's just the line where they do know and they don't know and every day they're going to be discovering things on experiments that have never been run before and figuring out things that have never been discovered. It's so exciting. That's going to be the most fun to see that every day. (I.R., Ph.D., Interview 1, lines 863–871)

> S: . . . it's like what do you call it? Like frontier land, sort of. You know, it's like people have general ideas about things, I mean it's based on a lot of factors, some of it's theory, but it seems like it's always changing and you can always make new discoveries. I guess I like the fact that it seems like you can always find something or be on the brink of discovery. (M.L., Ph.D., Interview 1, lines 271–277)

> I: When you think of research, what comes to mind?
> S: Finding something. Looking for something. That's what I think of. Just searching for something probably that you want to know, or sort of don't know, or maybe even coming up with something that has never been thought of before. You know, adding to someone else's ideas, train of thought. (V.M., Ph.D., Interview 1, lines 134–139)

> S: It's what I am. I think that I am a scientist. . . .
> I: You said you are a scientist. What is a scientist?
> S: A scientist? . . . The main thing is probably curiosity and maybe the want or the need to find an answer to a question just because it's unanswered. I think that I have that. (D.T., M.D./Ph.D., Interview 1, lines 404–414)

In addition to the students' words, the almost instantaneous responses, tone, and enthusiasm revealed how important and motivating this thrill of discovering something that had never been seen before was for the research-oriented students.

2. Enjoyment of Problem Solving. Another characteristic that had some similarities to discovery but was articulated differently was the enjoyment of solving problems. Consequently, this idea was coded as a separate theme. Ten of the 12 students who persisted in Ph.D. or M.D./Ph.D. programs articulated this concept. Although the enjoyment of solving problems was commonly talked about, it appeared to be less important than curiosity to discover as the primary motivator to do research. Additionally, the audiotapes indicated problem solving was not mentioned with the same enthusiasm as curiosity to discover.

> I: Has being here this summer changed your mind in any way about doing research as a career?
> S: I don't think it has. I have an inquisitive nature so that kind of fits right in with research. So from what I've seen I know that all research is not for me but I think there's an area that I'll really enjoy someday. And I know that I do need to do research just because I like coming up with questions and seeing if they're right or not and coming up with different methods to attack problems and see which one works.
> I: It's interesting that you say I know I need to do research. Not that I want to do research but that I need to do research.
> S: I think in the want, there's a need as well. You could interchange them. (G.P., Ph.D., Interview 2, lines 214–219)

> I: You were talking about learning that failure was a part of research—learning this from your previous work.
> S: . . . when I first started working in the lab, it just killed me to see nothing for three months. But I still learned from it and I learned what I was doing wrong and different ways to fix it and you get . . . real creative . . . you might spend a whole day thinking what can I do to prevent this gel from leaking out the bottom. . . . So finally you look at everything at the lab and you find something sticky and you say, "I'll try

this." So you try Vaseline or something so it makes you very creative. So when you're trying to rig something up—it just makes you creative when things aren't going right. (A.J., M.D./Ph.D., Interview 2, lines 414–429)

S: Whenever you're doing a (class) lab you know what the end result will be and what this is going to prove. Whenever you do an experiment in an actual working lab, . . . you're trying to find the answer to a question so the results you get, you have to figure out whether the experiment just went wrong or whether these are actually the results. So there's a lot more thinking about what happened and what you're using and what the results mean. There's more interpretation of the results I think.
I: How does that feel?
S: That's exciting. This is what I want to do. I want to find answers to questions. Whenever you're in a lab at school, you're in a class, you're doing this and it's more fun when you're doing it for real, let's put it that way. (D.T., M.D./Ph.D., Interview 2, lines 373–390)

As the excerpts indicate, these students were excited most about the idea of discovering something new, something that was unknown. Words like "cutting edge," "frontiers," and "discover" were commonly used. Solving problems that required ingenuity also excited them. The frustrations often found in laboratory work were seen as a challenge to be overcome rather than an annoyance or reason to do something else.

3. Independence. All of the students who expressed the intent to do research in the future talked of being able to (and/or seeking out situations where they were allowed to) think or act on their own with limited consultation or guidance from others. In contrast, none of the students who ultimately chose nonresearch directions displayed this theme. For many of the research-oriented students this desire to be independent was expressed as something very important to them.

I: It sounds as if you think you have grown and changed some. What is your current view of and interest in research now?
S: I'm still interested in research. It's made me want my own lab even more because I want to be able to do research under my terms. I see people who don't make a big commitment to research and end up doing it not full-time or 50% of the time—not making a full commitment to it and I don't want that. I want my own research. I want to be sort of captain of my destiny when it comes to what research I do and what the people in my lab are focusing on. (B.J., M.D./Ph.D., Interview 2, lines 416–425)

I: Why motivated?
S: Because I think there's a lot of things I want to do with my life and I think I have a lot of personal motivation to get things done. Like I don't have to rely on others to tell me things—not tell me things but encourage me. Like with the teacher that I'm motivated enough on my own to go out and do more than I need to do. (M.N., M.D., Interview 1, lines 585–591)

I: So what makes you feel that you want a career as a scientist?
S: I guess its high school, since I went to a medical magnet; it was all I've wanted. I've always loved science. I haven't been that good in math, and I wanted to be a scientist. I went to a medical magnet to experience different things and through there I got involved in different researches. It was like, "That's what I want to do. I want to work in a lab." I like finding something using my analytical skills. It's like you're trying to search something and I really enjoyed that. It's very independent, like you go in there and they teach, and you're on your own and no one's looking over your shoulder, "you need to do this—you need to do that." I like that independence—learning new things by yourself that they just give me a protocol and I can do it. Maybe not perfect the first time. But I am my own woman and you learn little tricks so it's very independent and I like that. It's an individual job. (V.M., Ph.D., Interview 1, lines 43–55)

4. Helping Others Indirectly through Research. Not surprisingly, the motivation to help others emerged frequently. Unanticipated was the observation that 24 of 26 students articulated this idea, including all nine of the students who entered Ph.D. programs. Although Ph.D.s and M.D./Ph.D.s spoke about helping others as frequently as those who went on to an M.D., the nature of how they saw themselves helping others was different. Generally, the M.D.-bound student talked about helping others through direct care, whereas the Ph.D. and M.D./Ph.D. indicated they wanted to help others but more indirectly through research.

Following are three examples of statements from students who wanted to help people in their chosen career paths. In the first example, the M.D.-bound student made it clear that what made volunteering fun was helping people out and what will make medicine important as a career path is the direct impact on people's lives.

I: So what makes you think that M.D. will be better?
S: Well I volunteered at hospitals before. I actually volunteered 2–3 years in high school and I did it the summer after my freshman year. And I've always enjoyed it. It's always something that I looked forward to and I had fun doing.
I: What made it fun?
S: The people, mainly. Just helping people out. I guess a sense of satisfaction that you did something for someone else and not for selfish reasons. . . . (Q.E., M.D., Interview 1, lines 1076–1086)

I: What do you think you'd get out of a career of medicine?
S: I think helping people is a big thing that's important to me—is having an impact on others and it's more important to do things like that. What I do for myself is good but it's what effect you have on the world and what effect you have on the people around you that's really important. And so I think medicine is a profession where you have a direct impact on making people's lives better. (M.N., M.D., Interview 1, lines 397–405)

The next two excerpts illustrate that the Ph.D.- and M.D./Ph.D.-bound students also want to help others but more indirectly through research.

> I: But when you think of "making a difference," how do you define making a difference?
> S: Many ways. One of the ways that comes more clear to me would be changing someone's life from worse to better. . . let's say I'm working with asthma or something and I develop something that will prevent them from suffocating or needing a ventilator every time they get wheezy. I have made a difference in their life making them more comfortable. (D.J., Ph.D., Interview 1, lines 200–207)

> I: When you think of the projects that you would like to work on, in your experience over the last few years, what are the ones that you think will end up being most interesting to you? What are the characteristics of these projects?
> S: What is always the most interesting for me is something that ties in directly with the outside world. Has a direct application like maybe designing a new drug that you can test. Even if it is on mice, but if you know it will help a human at some point, that is always really satisfying to me. . . . I am definitely interested in actually making something that I can see in the world later on and that has an impact on society. (M.C., M.D./Ph.D., Interview 1, lines 595–618)

The interviews showed that Ph.D.- and M.D./Ph.D.-bound students presented a very different sense of helping others by using their research. Additionally, they had a realistic view that their research *might* help people some day rather than a naïve sense of guaranteed and quick success. In contrast, the M.D.-bound students were motivated by direct care and treatment. Thus, the desire to help others did not appear to differentiate or predict the future academic directions of students, but the nature of how they hoped to help others did differentiate future directions.

5. Approaches to the Future. A very common question asked students in standard application interviews for entrance into Ph.D. or professional degree programs is where they see themselves in the future. This question is asked as an attempt by the interviewer to predict whether someone will persist through the education or training program the student wishes to enter. In analyzing the student responses to this question in our study, unexpected patterns emerged that clearly differentiated research-oriented and M.D.-bound students. When asked where they saw themselves in the relatively near future and in 5–10 years or longer, responses varied not only with what they would be doing but also with the clarity with which they saw the future.

Two basic patterns emerged. In the first, students expressed clear and often well-thought-out goals for the future and plans of how to attain them. These plans often included both professional and personal goals and a strong sense that they would be able to attain whatever goals they had set for themselves. Their planning often included strategic decision-making to achieve sequential steps along the way to a desired goal. In the second pattern, long-term goals tended to be more vaguely defined, often expressed as several possible outcomes with minimal concern or worry about which one would be achieved. These students often were more focused on pursuing interesting opportunities as they moved toward their stated professional goal. Some students made it clear they really didn't want to worry about the long-term future and sometimes were exasperated that everyone kept asking them about what they planned to do. This group seemed to actually enjoy, seek out, or create options rather than focus on moving directly toward a single goal, and this approach tended to be part of both their professional and personal lives. This second group we have termed as having a minimally structured view of the future.

Clearly Defined Approaches to the Future. This theme was articulated in several different ways. The excerpts below show how the students not planning to pursue research thought about how to achieve their future goals. They were often very focused about doing just the right things or picking just the right school so that their long-term future was assured.

> I: Again you've thought this all out very well.
> S: I'm kind of compulsive about it. I'm a big planner. I planned out my. . . what I kind of wanted to do for college, you know, all the way through my senior year. Things I would do to be successful in medical school application process, that kind of thing, from actually Christmas vacation my freshman year I started thinking about, "What do I need to do? What kind of experiences do I need?" Not only to list them but also to be good for me. That way I can be a good physician so. . . I do this a lot. (G.T., M.D., Interview 1, lines 1121–1130)

> S: . . . applying to a school like (school name) is very good because it's like a guaranteed job in that if you graduate from (school name), they'll probably be more likely to hire you. . . that's incentive, because I think when you go to medical school, besides the getting in, I think you should look at what are you going to do afterward because um, I know there are a lot of people graduating with M.D. degrees and there aren't enough positions so you want to make your resume sparkle as much as possible.
> I: You're planning!
> S: Yeah, I think it's important to look ahead. (W.A., M.D., Interview 1, lines 582–595)

For other students, planning was very particular and structured. They planned each day very carefully in order to accomplish many discrete goals and reduce the stress associated with not meeting their goals or to not doing well in what they set out to do.

> I: What would happen if you didn't make a list?
> S: I think things just wouldn't be clear in my mind. . . . Making those lists makes everything sort of important. Makes everything in my day-to-day worthy of paying attention to. . . . It keeps me in tune to my every day reality.
> I: It helps you focus?
> S: Yeah, I probably wouldn't focus without it. Goals I can set—I can't watch this number of TV, I have to go back to work now, I have to do this thing. It sort of keeps me really focused on the things to be done. It's good. (H.A., M.D., Interview 3, lines 211–231)

> S: I am not going to play soccer next year because it does take up so much time and I don't know if it's fair to my section for me to be gone that much. I volunteer for a lot of things, "Sure I'll do it. I can take on that." Part of it's a control thing. I like to be in control and I like to plan things and I like to plan out what I'm doing so that I can fit in more things and get more things done and it's common for me to go from class all day to a meeting to something else, another meeting or another activity. That's just pretty normal and that's fun. You might as well get as much out of life as you can. No reason to be sitting around. You might as well be doing things. (M.N., M.D., Interview 1, lines 677–686)

Yet other students talked about long-term goals as having very definite time-bound outcomes. Goals were thought-out. In addition, the means to the goals had been planned.

> I: So when have you planned the children?
> S: Actually, if I get married in med school, which I'm hoping, I don't have anyone special right now. . . . Let's see, after residency, actually between residency and fellowship, I'm thinking. A friend who works as a consult for an HMO organization, she comes in 20 hours a week as a pediatrician. . . . I'm planning to do that when I have kids. Take about 3 years off so I can stay home. . . more time when they're very young. . . seeing my sister's experience, trying to work full time and take care of the first one, very demanding child. . . . I realized that I didn't want to have a very long schedule when I had kids for at least a couple of years, then I'll go back to work. . . . in other words, finishing my fellowship and finding a job, getting to be a professor by age 36 instead of age 34 doesn't make that much difference in the scheme of things. (G.T., M.D., Interview 1, lines 1098–1119)

Minimally Structured Views of the Future. All nine of the Ph.D.-bound students and three of five future M.D./Ph.D. students talked about the future as having many possible options and long-term possibilities after completing their training. Further, they showed little need to know in advance which path they would end up taking, often seeming to prefer not knowing or having to work toward one outcome. This was expressed in several different ways but in each case revolved around a sense that they can't and don't need to precisely define the future.

> I: So you're definitely planning to have research as some part of your career.
> S: Right now. Who knows. . . . ? I just like to leave the door open because just talking to people—the professors or something—most people don't end up in what they think they're going to end up in college so I'd like to say for sure but right now that seems like where I'd like to be. (G.P., Ph.D., Interview 2, lines 222–224)

> I: How do you think you're going to arrive at a decision (between Ph.D. programs)?
> S: Since I was invited to all of them, I'm just keeping an open mind and just gathering all the information I can and get a feel, an impression of the campus, and sort of sample the attitude of professors and graduate students from there, and then also see what sorts of programs they have in addition. For instance at the University of (name) they have opportunities to take a year off during your second year and get a master's in epidemiology. And they have opportunities to do one lab rotation in industry to get a taste for a biotech company. So just those sorts of things to see what else, besides just a straight Ph.D., what else is available, what else is there. So that will also factor into my decision. (G.T., Ph.D., Interview 3, lines 337–349)

> I: What are your current plans for your career and/or your next educational steps?
> S: I applied to several graduate schools and I was invited to interview to several of them and I decided to accept. It was one of the things that attracted me to some of the programs was the fact that you did not have to decide a certain department to go into. I guess one thing that Mayo did expose me to was the fact that even though immunology was one aspect of the big picture, there are other things I still might be interested in and I should probably figure that out before I make a decision if I am one to do immunology research. That really helped me see that I could do immunology but there's other things that I could do in other areas: molecular biology, cell biology. . . . I looked for programs that did not require a commitment to a specific department. (I.R., Ph.D., Interview 3, lines 150–163)

> S: I think one thing in terms of expanding my horizons is that when I came in, I planned to do Ph.D. definitely. Then I started thinking about medicine. I've decided I don't want to do medicine. But actually what I'm thinking of doing now is maybe going into public health also. . . . I think it seems really interesting and it's something I would consider doing in addition to research, maybe getting a Ph.D. and then a Master's of Public Health. So just because I think that gets more into the large scale in terms of diseases, epidemics, of disease, health care, health care administration, that kind of thing I think you could get more into the larger impact. (M.L., Ph.D., Interview 2, lines 392–404)

From these data it was clear that the research-oriented students expressed a minimally structured future view with limited interest in trying to achieve a specific long-term career and/or personal outcome. Although their immediate plans included completion of the Ph.D., these students recognized there would be many interesting opportunities that would shape their long-term futures. This attitude is a contrast to the students who elected to pursue only clinical medicine. Review of the interviews with many of the other students in the study confirmed that this theme of comfort with a less structured or defined future was highly consistent among students who persisted toward research training and careers.

Students with Strong Research Interests Who Chose Medical School

In most cases, students who chose to enroll in M.D. rather than M.D./Ph.D. programs exhibited the profile and interests to pursue clinical medicine. By contrast, most of those who enrolled in M.D./Ph.D. programs appeared headed for primarily research. However, a third group of students showed a more complex pattern and/or changed directions

during the course of their graduate training. This group of five students included two who started into M.D./Ph.D. programs but then dropped out of the Ph.D. portion to complete only the M.D. and three students with an interest and intent to do clinical medicine and research but who consciously chose to do so with the M.D. alone. An analysis of these five students provided insights into how students made those choices when faced with apparent conflicting interests in research and clinical medicine.

One of the two students who dropped out of the Ph.D. portion of the M.D./Ph.D. had a strong curiosity to discover but also a very strong, perhaps stronger, desire to directly help others and had a clear preference for planning to ensure a predictable future as shown by the quotes from this student's interviews.

Curiosity to Discover Something New

> I: Have there been any changes in your perception of research or your interest in research as all or part of your career after having been part of this program?
> S: Yes. I don't think I could get away from loving research, just because the curiosity and the desire for learning new things is always going to be there. Now that I've had experience in working with very, very basic molecular science and now working with patients, I honestly can't say which one I like best yet. I have two extremes and I've done a whole of in the middle and for that I am so fortunate. Not many people are able to do both types of research at this young of an age. I know that I definitely am lucky to have a very diverse background in research. I also know that I do like both types. It's definitely opened my eyes to several opportunities of research in the future. (A.R., Interview 2, lines 636–650)

> I: How does that make you feel when you say "the more you learn, the more you need to learn"?
> S: I just think it makes me feel happy because it shows that nobody can ever know anything because everything is always changing. It's very challenging but at the same time, you're working with other people who are very dedicated and you're able to make a lot of good connections in that way because everyone is trying to reach a goal, whether they are looking for an answer to the question or whether they are trying to develop more questions to attack a problem from all kinds of different angles. Research is very challenging and difficult, but it's still rewarding because you're trying to figure out something that no one else has ever attempted to look at. (A.R., Interview 3, lines 269–280)

Strong Motivation to Help Others Directly

> S: If I can have 15 young men out there and I'm there giving them life skills, giving them pride, giving them hope. If I can get through to one of them at least, then that's one person who you don't have to worry about robbing the liquor store. That's one person you don't have to worry about carrying a gun and getting a little bit upset and pulling it out and shooting someone. That's what I can do for my neighborhood, for my family and the earlier that I can start with them, the better because I can get them onto the right track. And if they're going along, to mentor them to stay on that route. (A.R., Interview 1, lines 537–545)

Planning to Achieve a Clear Goal

> I: Why do you think you're a planner and I say this as one who's not?
> S: From the very day that I got into college I saw that you had to be organized in order to know, "OK at 10:00 I have to be here, at 12:00 I have to be here." It kept my life in order. It's really decreased the stress level and I don't get caught up—I'm not a procrastinator. I know when I have to do things and you know I've set up a schedule for my application, it's done and typed out and ready to go. All I need to do is decide what schools I'm going to go to. But that's something that became a part of me. I saw that I couldn't rush into things and I couldn't wait until the last minute. So being that I'm a very busy person, I have to really map out my days. Map out my months and decide when I'm going to do certain things and how long I'm going to do them. (A.R., Interview 1, lines 189-1102)

The other M.D./Ph.D. student, who dropped out of the Ph.D. portion after three Ph.D. years, fit the pattern of the research-oriented students but got frustrated when her research got bogged down and her committee would not assure her she would get her Ph.D. by a specified date. By that time, she had also decided she wanted to do descriptive rather than exploratory research in the future and did not feel more time in the Ph.D. would be of value (M.D./Ph.D. Program Director, personal communication).

Of the three students in this group who chose to do only the M.D., all had considered the M.D./Ph.D. but decided against it. One student wanted to do clinical rather than laboratory research. She displayed strong curiosity to discover but decided the clinical/translational research she wanted to do could be accomplished without the Ph.D., as shown by the following quotes:

Curiosity to Discover

> I: What do you like about research?
> S: I think the discovery. . . . Like if you have a toothache and you have a headache and you take Tylenol, how do you know it's just going to affect your tooth or your headache. Or if you cut yourself or you have a bruise and you're sore, how do you know what it's going to affect? What we're working on is just getting what you want to be affected. Your head doesn't hurt so you don't want your medicine going there, how are you going to deliver the drug so it just affects your teeth or your bruise or something like that?. . . . —figuring out how all that works. . . . There's a whole system of cells and proteins and delivery systems and second messengers and all that stuff you have to account for to make the medicine work. Or problems you're going to run into. Like if you put the medicine there, how do you know it's not going to trigger something else. . . . Figuring all that stuff out so that people feel better or can function better—things like that—I think that's absolutely wonderful. Yeah. (A.I., Interview 1, lines 259–280)

Undecided between M.D. and M.D./Ph.D.

> S: Yes. I'm going to medical school. I'm trying to decide now if I want to do an M.D. program or an

> M.D.-Ph.D. or even just strictly a Ph.D. I don't have to decide yet but I'm kind of looking at everything and seeing what I like and seeing how long it's going to take me and things like that.
> I: What are some of the pros and cons that you're looking at right now?
> S: If I was strictly an M.D. and I'd practice for a while, I wouldn't be able to do much research. I might be able to collaborate with a Ph.D. or an M.D./Ph.D. on something they were doing and be the person who did the clinical trials or patient-based research, and I wouldn't be in the lab very much doing hands-on experiments because an M.D., I wouldn't have too much time to be designing experiments and following through. I might have a team but I would probably need more contact with them than I would have. I probably wouldn't have all the necessary tools to do research properly as strictly an M.D. M.D./Ph.D. would take a lot of time. I'd be in school for a really long time and I don't know if I'd be able to devote enough time to both things. (A.I., Interview 1, lines 341–357)

Decision for M.D. and Clinical Research

> S: Next year is when I apply to medical school and I think I've decided against an M.D./Ph.D. but I would like to do research training because I would like to be a medical scientist/medical doctor and be able to have the proper training and proper research technique to translate mostly clinical research, but to do it properly and to do it well. So I'm going to incorporate research training into my medical school, either before I go or after my second year probably.
> I: I have to ask because you've said this a number of times. You've talked about being a medical scientist. Most people just say doctor. What's the difference?
> S: In talking with our pre-med office and deciding what path I was going to take—M.D.-Ph.D.? "No, M.D. but I want to do research." He said, "Say a medical scientist." I want to be able to translate different situations in the clinic. (A.I., Interview 2, lines 173–184)

Another student displayed high curiosity and comfort with an unpredictable future but in the end chose to do the M.D. instead of the M.D./Ph.D. He chose to apply to medical schools that would allow him to continue doing research. After the summer research at Mayo, he was convinced he wanted to include research in his career in some way.

Curiosity to Discover

> I: When you think of research, what comes to mind?
> S: For me research is really discovering new things. I think that's the part that really interests me, that you're the first person to discover something, and you're really going into uncharted territory. For me that's really exciting. I think it's really neat to discover something for the first time and especially some sort of discovery that has an impact on humanity and it satisfies some sort of altruistic me in that sense. But more than anything else, I think it's just exciting to be on the forefront of discovery and charting new territory.
> I: Do you picture yourself coming up with a cure for cancer?
> S: It doesn't necessarily have to be something as big as cancer, but even the littlest things. I did some synthetic organic chemistry research in the past, and we weren't solving cancer, but we were working with cyclopropanes and they're involved in fertilizer. Even though the actual impact and practical application was down the road somewhere, I think it was really neat and exciting to be working this reaction that other people hadn't been working with. It's nice when there is a big impact, but it's still pretty neat from a purely basic science point of view. (B.J., Interview 1, lines 79–95)

Open to Future Options

> I: Why did you decide that you needed a liberal arts background?
> S: I think for me being well rounded, I've always placed a great deal of weight on being a well-rounded person. I've always enjoyed the sports and I've never been one to focus intently on one area, at least in this point in my life. Maybe at some point down the road. I'd want to focus on one thing, but I've always enjoyed experiencing the wide variety of opportunities available to me whether it be sports or in the classroom. I was always curious about politics or economics or math, and I think that coming of high school, my high school background was liberal arts oriented, and I place a great deal of value on that and decided I wanted to continue that in undergraduate. (B.J., Interview 1, lines 41–49)

M.D. versus M.D./Ph.D.

> I: Are you considering medical school?
> S: Yes I am. I wrote the MCAT in the spring, and I'm just waiting to get those results back. . . . But the M.D. program or M.D./Ph.D. program both interest me, so they're possible avenues. (B.J., Interview 1, lines 120–123)

> I: What is your current interest in and view of research?
> S: Like I said, it's definitely something I want to pursue. I enjoy doing it. It's definitely a valuable experience, but as I say, I'm not going to pursue the M.D./Ph.D. route, at least at this point I'm pretty sure I'm not going to, but I do want to get involved in my first years of med school with research, and I'm thinking of the cancer area, like I was involved in oncology this past summer. (B.J., Interview 3, lines 136–145)

The third student vacillated between M.D./Ph.D. and M.D., struggling to make a decision, but eventually elected M.D. training. She continued doing research during medical school and ultimately into residency with the goal to have a largely research career. Her profile as an undergraduate was more like those who chose clinical paths, but when interviewed she was still trying to find what combination of clinical and research work she preferred:

Curiosity to Discover

> I: What makes research interesting to you?
> S: Probably that here—you take all these science classes and you read about all these people that make revolutionary discoveries and things that helped moved along the scientific and medical field to where it is now—and to think that maybe something you

could do could find a technology that detect cancer, rather than 10 years down the road when you normally would find it, maybe two years down the road where the survival rate would be even better. Just that there's so much unknown out there, and that hopefully you'll be able to explain and understand some of this unknown that could help.

I: Have you thought about what kind of research you'd like to do?

S: I'd like to spend some time, if not a lot of time, doing cancer research—it's something that I think is very important and it's an area that really interests me.

I: Why cancer?

S: This is like the question, "Why do I like physics?" I don't know. It's just an area that really intrigues me. I took the train out here—it took me two days to get here—and I had a packet of papers that I had been given by a physician that I had shadowed in December. It was a lot of different things on breast cancer. There was a lot of technical stuff but I was just sitting there reading it like it was a novel. I don't know—I'm so used to having painful reading—something that you just have to get through for classes or different things. (B.L., Interview 2, lines 399–430)

Clinical versus Basic Research

I: What are your career goals and plans at this time?

S: Well, I know I want to go into the medical field—this is the field where I want to be. Whether it's doing research or clinical—right now I'm thinking of kind of a cross between the two. What—I have no idea yet. So far—in three days—this summer has been a success. If I had to leave tomorrow what I've done in three days has been phenomenal—the things I've been able to experience and be a part of. So, ten weeks should be a good kind of testing point. The area I'm working in now basically I think is going to be all research, which is fine. It's something I want to see. But I definitely think I want to have some kind of clinical aspect too. (B.L., Interview 1, lines 354–365)

I: What is your current view of research? Are you still planning to have that as part of your future?

S: I definitely would like to. I enjoy it. I think I'd like to get into something more tumor biology related. I've sort of determined that I don't like physics enough to want to stick with it into the long distance future. I really liked being able to understand cell pathways and I can see it in my head. That's really something that interests me. But at the same time I really like to work with patients. So somewhere in there finding a happy medium would be optimal. (B.L., Interview 2, lines 326–336)

These five students provide good examples of the complex decision-making required of students drawn to both clinical medicine and research. The themes their interviews revealed were very similar to those who pursued Ph.D. or M.D./Ph.D. degrees (i.e., curiosity to discover and comfort with less clear future paths). However, either a conscious decision to do research with the M.D. degree, or competing interests to provide direct care to patients and/or have a secure and more predictable future, led them to choose paths other than the Ph.D. or M.D./Ph.D.

Initial Hypothesis Testing Using Surveys

Analysis of the students' interviews suggested there were a very limited number of themes that predicted which students would persist toward a research career. To test this hypothesis further, a new question was added to the anonymous end of summer survey given to the SURF students. Historically, ~50–70% of SURF students completed the rather lengthy online survey, often providing extensive text comments.

The following question was added: "If you are currently planning to pursue a research career as a Ph.D. or M.D./Ph.D., what do you find attractive about doing research? Why have you chosen it as a career path?" Survey completion results are provided in Table 3. "Presumably, those students who completed the survey but chose not to answer the new question (29 of 84 students over the two years) did not plan on a research career."

The coding developed from the interview study was used to analyze the survey comments for 2002 and 2003. If students gave two or more distinct reasons for planning to pursue a research career, they were each coded in the appropriate category with notation of which one came first (possibly indicating the first one that came to mind). Table 4 provides a summary of the analysis of the comments of the 65 students who answered the new survey question over the 2 years.

Almost all of the responses were easily coded within the same themes found in the interview study. The themes of curiosity/discovery and problem/puzzle solving were mentioned by 83% of the students who answered the survey questions both years. Other consistent themes coded were as follows: help others (34%), independence (12.5%), and creativity (5%). Examples of the written comments and their coding follow:

"I feel it is rewarding to discover new things, especially those that can help people. It is also just really interesting." (Discovery first, Help others second; 2002)

"I like the idea of discovering things that no one has known before and that the research I do will contribute to the greater scientific knowledge about a topic. I also hope that my work will someday be used help to treat human disease." (Discovery first, Help others second; 2003)

"Working in research is like a puzzle; it is up to the researcher to find different methods, different approaches, and different methods of reasoning to solve the problem. It can be frustrating, but it lets one exercises all areas of the brain and be a little creative. (Puzzles/Problems first, Creativity second; 2003)

Table 3. Survey and new question response rates

	2002	2003
Total SURF students	73	86
Completed survey	45 (62% of 73)	49 (56% of 86)
Answered new question	30 (67% of 45)	35 (71% of 49)

Table 4. Answers to: what do you find attractive about doing research? and why have you chosen it as a career path?

	2002			2003		
	First reason[a]	Additional reasons	Total[a]	First reason[a]	Additional reasons	Total[a]
Discovery/curiosity	15 (50)	1	16 (53)	18 (51)	2	20 (57)
Puzzles/problems	6 (20)	3	9 (30)	5 (14)	4	9 (26)
Independence	1 (3)	2	3 (10)	1 (3)	—	1 (3)
Help others	5 (17)	6	11 (37)	6 (17)	5	11 (31)
Creativity	1 (3)	1	2 (7)	1 (3)	—	1 (3)
Other	2 (7)		2 (7)	4 (11)	1	1 (3)
Total individuals	30			35		

[a] Values are the number of individuals with the percentages in parentheses. The percentages given are of those who answered this particular question, i.e., those who answered affirmatively to the intent for a research career.

> "Doing something no one has ever done before, it is exciting. Also I like the teamwork of lab members. It is something that I can see myself being happy with down the road. . . . " (Discovery; 2003)

> "I like to try and solve puzzles and hunt for knowledge that might be able to help others live better lives some day. I could do this in other career outlets, but I enjoy doing science; that makes all the difference." (Puzzles first, Help others second; 2002)

> "The flexibility and the independence is what really attracts me to research. In addition I also love science and answering challenging questions!" (Independence; 2002)

> "I am planning to pursue a career as an M.D./Ph.D. because I believe that a tighter correlation between basic science experiments and clinical application can help a researcher to make his research reach people more quickly." (Help others; 2002)

> "I plan on pursuing an M.D./Ph.D. I feel that this career path will lead me to doing research that will easily translate into clinical applications. I want to be a part of making health care better and I feel that this is the path most conducive to doing that." (Help others; 2002)

The students' word choice in both surveys was remarkably consistent. Most consistent in both years was the idea that research offered these students the opportunity to answer questions that had not been answered before. Although helping others through research was a frequent theme, discovery/creativity or problem/puzzle solving was almost always mentioned first.

SUMMARY AND DISCUSSION

This research study was initially undertaken to determine whether it was possible to identify underrepresented minority students most likely to persist toward a Ph.D. or M.D./Ph.D. and eventually a research career. This desire was born of the minimal progress being made in the 1990s toward increasing the representation of these groups in research and particularly in academic faculty ranks. If patterns could be identified, then it would be possible to target resources, which are always limited, toward those individuals for whom they would have the most benefit. Also, if one could identify those elements of a research career that were most attractive to these students, then programs could be more precisely designed to promote research careers. What emerged during the course of these studies, however, was a series of themes that appear to be highly consistent among undergraduate students who continue on toward biomedical research training and careers irrespective of their ethnicity or gender. Although not necessarily surprising in retrospect, the consistency of the themes and the differences between students who articulate them and those who don't were striking. Used appropriately, these themes may provide improved methods for not only identifying future scientists but guiding students struggling with career choice decisions.

The most demonstrable theme that consistently predicted those students who persisted toward research after college was a curiosity to discover the unknown. This theme was consistently expressed in initial open-ended interviews and subsequently in a focused question on the web-based survey of undergraduates doing summer research. For many students there was almost an immediate response to questions that probed why they liked research. Unlike other questions, which often required reflection to formulate an answer, the pure joy of discovering something new seemed to be well formulated and ready to be expressed. Curiosity is something that is frequently seen in young children but is often lost or tempered as they mature. The students who are attracted to research appear to have held on to a strong sense of curiosity and applied it to the scientific world. As they have grown and matured, this curiosity has been refined from a curiosity to know what is known to a drive to discover what was previously truly unknown.

Although expressing a curiosity to discover something new, virtually all of the students expressed the desire to look for new information that might have a positive benefit for others. In most cases, this was couched as a qualifier to their desire to discover, but for a few students, discovery and helping others were very closely linked. Because all of these students were in a program doing biomedical research and obviously were attracted to it, we cannot know whether a similar altruistic element would be found in students drawn to research where the potential benefits are less obvious or concrete. Those students who chose to enter medical schools

uniformly displayed a strong desire to help others more directly and immediately. These two different expressions of a desire to help other could be easily differentiated in interviews.

The next theme expressed by most research-oriented students was the strong desire for independence, to make their own decisions, make some mistakes, and find their own way. These students did not seem to be concerned with getting everything right the first time, and they often didn't want to have people looking over their shoulders all the time. Many of them had made decisions to go into research and/or had made other life decisions against the advice or wishes of families, teachers, and mentors. For whatever reason, they appeared to have the confidence and drive needed to make their own decisions.

The final theme and the one that was least obvious or predictable was the comfort with and often the desire among the research-oriented students for a future with many possible outcomes rather than having a particular outcome. They simply didn't talk about a specific goal, beyond their next step, such as which graduate school program to join; they talked about different possibilities and options but seldom one specific career or lifestyle. These students did not come across as unaware or confused, rather as being aware of options but not in a hurry to commit to one or know ahead of time which one they would ultimately choose. This was in sharp contrast to those students who had decided on clinical medicine as their career choice. These students usually had thought carefully about the sequence of events ahead of them and their long-term goals and appeared to prefer a predictable path and future.

One of the advantages of interview-based approaches to research of this kind is that one captures the thinking and rethinking that students engage in over time. Thus, the logic of their decisions reveals important elements of consistency that might not appear on the surface. For example, three of the students elected to enter M.D. programs, rather than Ph.D. or M.D./Ph.D., but had many of the characteristics of those students who chose Ph.D. and M.D./Ph.D. training. Examination of their interviews revealed that they fully intended to pursue research as a major focus of their career but for logically expressed reasons or uncertainties had chosen the M.D. path to get there. By contrast, one of the students who entered a Ph.D. program never clearly articulated why she was doing it or where it would get her. She did not express the three key themes of research-oriented students to any significant degree. Apparently, and probably appropriately, she recognized that the Ph.D. was not the best direction for her during the first year of the Ph.D. program and chose to go to veterinarian school to earn the D.V.M. instead.

Are the key themes necessary and sufficient for predicting future scientists? It is our belief that they should be seen as likely necessary but not sufficient, particularly with respect to predicting career choices after completion of training. The research-oriented undergraduates were still at an age where everything seemed possible and time was plentiful. As they progress through graduate school into a different developmental stage (Baxter Magolda, 2001), with friends getting married, starting families, and starting to earn significant incomes, their plans for the future might become tempered with life's realities. The students in the study are completing their initial degrees, and they will have many different career steps. The data are not yet sufficient to allow any conclusions to be drawn, other than that some have gone on to traditional postdoctoral training and some have gone into other fields such as technology transfer. Subsequent studies could look carefully at the decisions students make to better understand the factors that affect their choices and opportunities after completing their degrees and additional training.

The two students who started out in M.D./Ph.D. programs but dropped out before completing the Ph.D. also support the hypothesis that the themes are necessary but not sufficient. One of the two had actually gone back and forth between M.D. and M.D./Ph.D. programs (having been accepted to both), started the M.D./Ph.D., but dropped out of the program before entering the Ph.D. phase. Although having a high level of curiosity and independence, his desire for a predictable life and the rewards of direct care to patients was too high to justify in his mind the long time in dual degree training. The other M.D./Ph.D. student who dropped the Ph.D. after 3 years also showed strong curiosity and independence. However, after 3 years on a project that did not progress very quickly, she became frustrated due to the unpredictable endpoints of research and a diminished interest in discovery.

When considering the necessary versus sufficient question, other critical skills and interests necessary to thrive in a research career must be taken into account. Simply having the characteristics identified in this study is unlikely to be sufficient. Students must still demonstrate the aptitude for learning science, the critical-thinking skills necessary for designing experiments and analyzing data, the persistence to take on challenging questions that don't want to be solved, and the creativity needed to solve them. All of the data currently used to make admissions decisions for Ph.D. and M.D./Ph.D. programs continue to be useful, but the results reported here would suggest that students who don't possess the key themes are less likely to persist in research.

Returning to one of the key questions of the initial study design, is there any evidence that the themes predicting those students who continue toward research careers are different among men and women, minorities and nonminorities? From this study, no. The themes were uniformly expressed across gender and ethnicity. Thus, there do not appear to be any systematic differences in what initially attracts a student toward research. What the study cannot say, nor was it designed to investigate, is the frequency or ease with which women and/or minorities arrive at or adopt the characteristics revealed in the themes. Women now constitute essentially half of the graduating Ph.D.s in biological sciences, suggesting they are heading toward research training equally with men (Science and Engineering Doctorate Awards, 2005). However, their progression up the academic ladder, admittedly only one of many career paths with a Ph.D., is still well behind that of men (Committee on Science, Engineering and Public Policy, 2006). Traditionally underrepresented ethnic groups continue to be highly underrepresented in Ph.D. programs and research, suggesting that there are still many factors limiting the fraction of students who reach the Ph.D. decision point like those in this study.

One important additional observation can be made with respect to underrepresented minority students choosing and feeling ready to enter Ph.D. programs. Because a higher

fraction of ethnic minorities come from economically and educationally disadvantaged backgrounds (Kozol, 1991; Carnoy, 1994; Lee 2002; College Entrance Examination Board, 2006), they are playing catch-up both academically and experientially throughout college. By definition, one has to run faster and harder in any race when one starts from behind. The NIGMS has recognized this important reality with the creation of the Postbaccalaureate Research Education Program (PREP; http://www.nigms.nih.gov/Training/Mechanisms/MARC/PREPAwards.htm) for students who reach the end of college but only realize that a research career is an option too late to apply to Ph.D. programs while still in college. The PREP program allows them to continue doing research at the intensity of what they will experience in a Ph.D. program and a research career and to make the final determination whether or not this is what they desire and for which they are well suited.

As already discussed in the *Introduction,* few if any previous studies have attempted to pinpoint predictors of students who will persist toward research careers. The studies of why students leave science majors in college, however, are consistent with what was observed here. In the study of 335 students across seven colleges and universities from 1990 to 1993, Seymour and Hewitt (1997) observed that a prominent reason math and science majors switched majors was their inability to see the major leading to work that was intrinsically satisfying. More engineering students made choices based on pragmatic employment and financial concerns, but math and science majors put less emphasis on these issues. This is consistent with our findings that virtually all of our students spontaneously talked about the potential social value of their work. The students who chose to pursue research in our study did see its value. When Seymour and Hewitt compared those who switched with those who did not, a much higher fraction of the nonswitching science, engineering, and math majors had entered the major for its intrinsic interest (28 vs. 11%) and altruism (5 vs. 1%). Their choice of major was less due to the active influence of others (13 vs. 20%), because they were good at math and science in high school (9 vs. 13%), or was based on an uninformed choice (6 vs. 13%). Thus, the students who stayed in the majors presented a group more likely to have entered the degree for internally driven and validated reasons. The study of Seymour and Hewitt also vividly portrayed the importance of the influence of early practical experience in shaping the perceptions of students about what one did with degrees in science, math, and engineering, whether it was an accurate or inaccurate perception. The students in our study who were choosing to do research were doing so because they had experienced the excitement of discovering something new, the independence it could afford them, and the potential positive impact on others it might provide. It would be very interesting to determine whether these themes were the same or different among students pursuing research careers in other fields, such as math, physics, engineering, and social science research.

Very recently, a report of a large survey-based research study of students who did undergraduate research has appeared (Russell *et al.,* 2007). That study revealed a great deal about the many positive impacts of undergraduate research on students, including "increasing somewhat" (35%) or "increasing a lot" (32%) students' interest in a career in research. These positive impacts of research experience confirm quantitatively what science faculty have collectively seen qualitatively for many years. What the survey did not attempt to study, however, is *how* undergraduate research affected the students, i.e., what was it about doing research that stimulated their interest to do more? One of the key questions in their follow-up survey asked "Which of the following statements about undergraduate research apply to you?" The 28 options included a wide array of knowledge, attitude, and skill options but did not attempt to determine which of them were or were not key in guiding students' decisions. The only option that would align closely with the results of our study was "I learned that I am a good problem solver." Based on the results presented in our study, we would predict that a new follow-up survey probing the decision-making of these students might be able to identify common themes among the students.

Implications, Limitations, and Future Studies

One has to be exceedingly cautious not to apply any simplistic or formulaic approach to choosing or predicting future scientists or prematurely tracking young students into any direction. To do so would fall into the same trap as believing a transcript or a standardized test score alone can predict success. But the observations of this study do suggest some key predictors that can help students find their "best fit" careers and guide our thinking on choosing students most likely to persist. The results would suggest that it is critical that students experience what research is all about at any early enough age to "capture" those who will be captivated by it. This is one obvious rationale for why high school and college science courses should include discovery-based laboratories rather than cookbook repetition of known outcomes. The thrill of discovery is likely the basis for why undergraduate research is so pivotal in the career decision-making of many scientists. The results would suggest that the analytical problem solving along with the discovery of something new, no matter how small, should be the key goal of early research experiences to stimulate the interests of future scientists.

These results suggest that the five themes could be useful in choosing students for Ph.D. and M.D./Ph.D. for whom research will ultimately be the best fit. What cannot be determined from this research, however, is whether or not the themes predict students who will ultimately be successful in other nonresearch careers that require the Ph.D. Because there are so many different career paths opened by a Ph.D. and for which the Ph.D. is outstanding training, one must be cautious not to select only for students who will be driven by the never-ending search for new information.

Another very important use of the results of this study is in advising students who are trying to figure out what to do after college, particularly those who like science but don't know whether they want to go into medicine, research, or some other option. Helping students identify what they think they will do in various careers and comparing it to what they would like or not like about those careers is always a crucial step in advising. Being able to add these three core elements of what attracts students to research careers should help other students determine whether they fit with what the career provides.

The results also suggest that it could be fundamentally very difficult to "convert" or reorient a student who is planning a career in clinical medicine toward a research career. The future scientists and future clinicians among the study subjects are fundamentally different people with different motivations and goals; they show minimal evidence of malleability between the two patterns, other than those students who communicate both sets of themes. The caveat to this conclusion is the small fraction of students who enter medical school each year who later transfer to M.D./Ph.D. programs or pursue research after their clinical training. Our prediction would be that these individuals possess the themes common among research-oriented individuals but had not discovered these interests early in their training or consciously chose a different route for their expression. It would be very interesting to determine whether those M.D.s who choose to do clinical research later in life also possess the patterns of these research-oriented undergraduates. The alternative hypothesis could be they choose to do research motivated by the potential for a direct impact on improved clinical care.

In a study of this kind, an important consideration is whether or not the results fit with how professionals in the field see themselves and what attracted them to it. In discussing these results with many successful scientists, virtually all agree that they would "fit" most or all of these themes. Although there is always some risk of bias in such an after-the-fact comparison, the fact that the results do fit the self-perceptions of successful scientists is an important initial confirmation.

Finally, interview-based research like this is very labor-intensive and thus limited to a relatively small sample of individuals. But the results can be tested using other methods. The addition of the new question to the end-of-summer SURF survey was the first extension of this kind. The results show the consistency of their answers, the support they provide to the hypothesis derived from the interviews, and the importance of the nature of the questions asked on surveys. Typically, surveys might ask "What do you plan to do after you graduate?" or "What future career do you see yourself in?" Responses provide numbers of replies but no insight into why the individuals are planning to do as they say. The simple change to the specific question of what attracts a person to a specific direction provided much greater insight into the thinking and logic of the individuals. Future surveys should be able to use carefully refined questions to reveal important new insights into the decision-making processes of future generations of students.

ACKNOWLEDGMENTS

The support of the Mayo Clinic for both this research and the initiatives in support of the development and success of students and trainees is gratefully acknowledged. The work was directly supported by a Grant R25 GM55252 from the NIGMS, NIH, as part of the IMSD.

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