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An Analysis of Factors That Influence Students to Pursue Immunology

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ABSTRACT

One considers many factors before choosing a career path, such as interest, accessibility of resources, academic ability, and social network support. As employment around the world in science, technology, engineering, and math (STEM) disciplines continues to increase, there is a need to understand why students select specific majors in an effort to increase overall enrollment and retention of STEM majors. The purpose of this study was to elucidate how undergraduate and graduate students were introduced to immunology, a STEM discipline, and how these experiences influenced their desire to pursue immunology as a major. The findings from this study show that a majority of both immunology and nonimmunology majors were initially exposed to immunology through an educational experience compared with a personal experience. Our data also indicate that the timing of the experience is critical, such that an educational experience at an advanced academic level, for example, in college, or a personal experience as a teen or young adult correlated with the decision to pursue an immunology degree. Moreover, graduate students studying immunology report that having research experiences and/or an experience with a mentor positively influenced their decision to pursue immunology. Overall, the findings from this research highlight the type and timing of exposures that influence individuals to major in the field of immunology, and these data can be used in the future to increase the number of immunology graduates.

INTRODUCTION

Science, technology, engineering, and math (STEM) education is not defined solely by the acquisition of a degree in one of these disciplines, but rather, it incorporates a teaching philosophy that merges the four disciplines into a unifying conceptual framework to foster the development of competencies that students need to achieve a well-rounded education and career success (1, 2). STEM education fosters the development of a wide variety of skills, such as critical thinking, problem solving, leadership, ethical conduct, teamwork, and communication. Over the next decade, STEM jobs are expected to grow by >8%, and healthcare professions, of which almost all aspects are shaped by STEM, by >15% (3). Thus, finding ways to increase the number of students who pursue a STEM education is critical.

There are several factors to consider with regard to increasing the number of students who are interested in STEM, and one important aspect is understanding what factors influence a student’s interest in and choice to pursue a specific field of study. For any individual, the selection of a college major is often a complex process, and the resulting decision can be influenced by a diverse array of factors (4). In addition to personal attributes, such as academic ability, self-confidence (5, 6), and personal interest (7, 8), which are critical driving forces,
access to resources and people who can provide insight about the major or field are also important external influences (9). Individuals report that their informal social network, such as family, friends, and community leaders, is a leading source of information and thereby influences the process of selecting a college major. The second source of information is from formal or professional networks, which includes high school and college counselors and various forms of media (9). Other influencing factors include the availability of appropriate role models, particularly for women and individuals from underrepresented groups (10–12), as well as an individual's socioeconomic status and the occupation of their parents (13).

Although understanding the factors that play a role in the complex decision-making process of selecting a major is important, the availability of a diverse array of STEM majors that will attract students to these fields is also critical. Notably, the focus in STEM education is on an understanding of the interdisciplinary nature of the information conveyed to students who pursue degrees that fall within the STEM disciplines. Indeed, several calls for reform in undergraduate biology education have been made over the past decade (14–18) to emphasize the interdisciplinary nature of science. Immunology, a field that studies how the immune system works, is inherently interdisciplinary given that the immune system is a complex network of organs, tissues, cells, and molecules that interface with all other organ systems in the body, and it plays a critical role in regulating complex physiological processes. Critical to understanding how the immune system works is the need to understand scientific principles in chemistry, biochemistry, genetics, and molecular and cellular biology. Furthermore, the interdisciplinary connections to technology, engineering, and math are demonstrated in the study of both foundational scientific concepts and the applied sciences relevant to immunology. The contribution of a comprehensive undergraduate immunology curriculum in promoting STEM education and interdisciplinary science has been discussed recently (19).

The University of Alabama at Birmingham (UAB) is currently the only institution in the United States to offer a dedicated undergraduate immunology major, the Undergraduate Immunology Program. Thus, the Undergraduate Immunology Program is in a unique position to assess what factors influenced students in the program to pursue immunology as an undergraduate major. Furthermore, access to the Graduate Biomedical Sciences (GBS) program at UAB, which houses eight themes of study, including immunology, allows this assessment to be performed at the graduate level as well. Given the importance of access to information and personal connections on the process of selecting a college major, this study sought to determine whether the introduction to immunology through personal experiences was more influential in the process of selecting immunology as a major than an introduction to the subject through an educational experience and to identify factors that may persuade students to select immunology as an undergraduate or graduate-level major.

**MATERIALS AND METHODS**

**Survey description**

A survey was developed using Qualtrics (Research Suite, Provo, UT) to gather data on factors that influence a student's decision to pursue immunology as a major. This study was approved by the UAB Institutional Review Board protocol #IRB-300005785-007. A consent form was sent to all potential respondents noting that participation was voluntary, the survey was anonymous, and the data would be kept confidential. The survey consisted of 19 questions that were organized into three sections. The first section included demographic data, such as academic level, major or theme, and career goal. The second section asked whether students were introduced to immunology through an educational experience, and the third section asked whether students were introduced to immunology through a personal experience. Importantly, all survey respondents were allowed to answer all three sections of the survey regardless of their individual response concerning whether they were introduced to immunology via an educational or personal experience. For the educational and personal introduction sections, respondents who answered “yes” were asked additional questions about the experience. If “no” was selected for introductions to immunology through both educational and personal experiences, students were asked whether they were introduced to immunology through other means. If “yes” was selected, respondents were prompted to describe the experience.

**Participants**

The survey link was distributed to 824 undergraduate students who were immunology majors or were in a comparable science program (neuroscience, chemistry, biology, or biomedical sciences) at UAB. There were 172 undergraduate respondents for an overall response rate of ~21%. A total of 98 undergraduate students were immunology majors in the 2020/2021 academic year, and 85 responded to the survey (89% response rate). It was also distributed to all 325 graduate students in the UAB Graduate Biomedical Sciences Program, which offers eight themes focused on different aspects of biomedical science, of which one is immunology. There were 111 graduate respondents for a response rate of ~34%. There were a total of 53 graduate students in the immunology theme in the 2020/2021 academic year, and 41 responded to the survey (77% response rate).

**Personal interviews**

Approximately 5 mo after the survey, UAB graduate students were asked to participate in a semistructured short interview (~10 min) to expand on the survey results. A total of 28 graduate students (both immunology majors and nonmajors) participated in the interviews. Virtual interviews consisted of six questions and were conducted via Zoom. Using a free speech-to-text Web-based application from Otter.ai (Los Altos, CA), the interviews were transcribed. Transcripts were sent to four...
coders to identify four words/phrases and decide whether they were in the context of a positive, negative, or neutral experience. The words/phrases were: (1) research or research program, (2) mentor, (3) immunology course (not part of anatomy and physiology course), and (4) student is doing immunology-related research currently. After their individual assessment, pairs of coders met to reach consensus on their interpretation of whether the four phrases were interpreted correctly as being positive, negative, or neutral in the context of the response obtained for each individual. There was >95% consensus on coding phrases among all four coders.

**Data analysis**

Based on demographic information provided by the respondents, four groups were compared: undergraduate immunology majors, undergraduate nonimmunology majors, graduate immunology students, and graduate nonimmunology students. The data were first analyzed by calculating the frequencies between nonimmunology and immunology students and, second, by comparing the frequencies between undergraduate and graduate students. To test for differences among proportions, χ² analyses were performed using SAS 9.4 (Cary, NC) to identify statistically significant differences between the groups. If expected respondent numbers declined to <10, categories were collapsed to achieve adequate power or Fisher exact test was used. For figures in which the emphasis was to display the variety of responses, statistical analyses were not performed.

**RESULTS**

Of the total number of respondents (283), 45.23% (128) of the students were majoring in immunology (IMM), whereas 54.77% (155) of the students were majoring in a discipline other than immunology (non-IMM). There was a greater number of undergraduate students (60.8%, 172) than graduate students (39.2%, 111) who responded to the survey, which was expected given that undergraduate enrollment at UAB in the fall of 2020 (10,402) was almost triple that of graduate student enrollment (3306). Overall, there was diverse representation across demographic variables among students in the study (Fig. 1A). There was equal distribution among respondents in regard to race/ethnicity and sex when comparing immunology majors with nonmajors. However, more respondents aged 18–20 y reported IMM, whereas more respondents aged 21–23 y reported non-IMM (Fig. 1B; *p < 0.014). Although it does not appear that differences in age between IMM and non-IMM respondents impacted the results, it is nevertheless a confounding variable within the study.

In the second section of the survey, respondents were asked, “Were you introduced to concepts about immunology or the immune system through an EDUCATIONAL experience such as part of a class, lecture/seminar, course, internship, private conversation with teacher or professor, etc.?” There was no significant difference between immunology and nonimmunology students who answered that their first introduction to immunology was through an educational experience (Fig. 2A). However,
at the undergraduate level, the introduction to immunology through an educational experience negatively correlated with a decision to pursue an immunology major \((p = 0.043; \text{Fig. 2B})\), but this result was not observed at the graduate level (Fig. 2C).

Respondents who reported having an educational experience were then asked when the educational experience occurred. When the undergraduate and graduate responses were pooled, there was no statistically significant correlation between the timing of when students were introduced to immunology through an educational experience and the decision to pursue immunology as a degree (Fig. 3A), which was similarly observed at the undergraduate level (Fig. 3B). However, with regard to the timing of an educational experience for graduate students, there was a negative correlation between an introduction to immunology in high school and a decision to pursue immunology. Conversely, there was a positive correlation between an introduction to immunology in college and a decision to pursue immunology \((p = 0.039; \text{Fig. 3C})\).

Certainly, the type of educational experience students encountered may have contributed to the differences in correlation between the timing of the educational experience and choice of major for graduate students. From the survey responses, the types of experience were varied among undergraduate students and graduate students regardless of major (Fig. 4). A unit/learning activity and lecture/seminar about the immune system were common examples of educational experiences reported by undergraduate students (Fig. 4A), whereas an immunology course was frequently reported by graduate students as the first introduction to immunology (Fig. 4B).

The survey did not contain specific questions that would provide insight regarding the quality of the educational experience or whether that experience played a direct role in the student’s selection of an academic major. Given that there was a significant correlation between the timing of an educational introduction and selection of immunology as a major for graduate students, such that more nonimmunology graduate students were exposed to immunology in high school, whereas more graduate students pursuing immunology were exposed in college, we conducted personal interviews with graduate students (both immunology majors and nonimmunology majors). Students were asked to describe not only the timing of the educational experience but also the type and quality of the educational experience and whether that experience influenced them to pursue (or not pursue) immunology. Of the 28 graduate students who participated in the interviews, 12 were non-IMM and 16 were IMM. Of the 16 IMM, 5 interviewees were excluded from the analysis. Two were excluded because they reported that their first exposure to immunology was through a personal (and not educational) experience. Three other respondents who were MD/PhD students were excluded because the descriptions of their experiences were a mix of...
educational and personal, and the timing was atypical due to their program.

Of the remaining 11 immunology graduate students, two respondents reported being initially exposed to immunology in high school, and their experiences were drastically different from one another. One student, who was introduced through a classroom experience, reported that it was a negative experience, stating that “I think immunology is very overwhelming if you try and skim it and that it really takes going into it in-depth to sort of make it less scary. So, it’s not something I really enjoyed until later in college.” The other respondent had the opportunity to work in an HIV clinic in high school and reported that this was a positive experience and thought “it was pretty cool, the treatments and learning about how to help HIV patients.” These responses provided some evidence that the type of exposure, in addition to timing, may be an important influencing factor when choosing to pursue immunology.

Further exploration of the educational experiences in college reported by graduate student interviewees revealed two influential factors: students who did research as an undergraduate to have a positive experience with a mentor (62.5% of immunology majors) were positive influential factors in the choice by graduate students to pursue immunology. In contrast, taking an immunology course as an undergraduate student did not appear to be a significant positive factor because 50% of graduate students who took an undergraduate immunology course chose to pursue immunology, whereas 50% chose to pursue other fields of study (Fig. 5), and responses from interviewees suggest that this may be a direct result of how the material in the course is taught. Both immunology and nonimmunology respondents who were introduced to immunology in a course reported that it was challenging and overwhelming. One immunology graduate student reported that “[the immunology course] was a lot packed into a single class. I feel like the university thought it would be helpful, but then at the same time I think it was sort of counterproductive because there’s just so much information you can get in a semester’s work.” Similarly, another immunology graduate student stated, “[immunology] has a lot of complex factors … if you start blurt out cells and not explaining what they’re doing and their roles and how they work together in a more simplistic way, it can easily kind of steer people by and turn them off because there’s so much that is involved within this field.” Many nonimmunology graduate student interviewees described similar feelings when they were initially exposed to immunology through coursework. When asked, nonimmunology graduate students described the following about immunology: “I’ve always pushed away from diving too much into immunology, just because it seems like a lot”; “It didn’t really catch my interest because it was complicated things that I had never heard of”; and “Immunology always felt incredibly overwhelming, especially as I progressed into graduate school because you’re throwing out a lot of terms … and you’re bombarded with this niche terminology.” These responses from both immunology and nonimmunology graduate students illustrate the importance of explaining complex immunology concepts in a simplified and clear manner that can foster student interest.
In the third section of the survey, respondents were asked: “Were you introduced to concepts about immunology or the immune system through a PERSONAL experience (for example, an informal discussion, vaccination, or disease encountered by you, a family member or friend)?” At both the undergraduate and graduate levels, there was no correlation between the introduction to immunology through a personal experience and the decision to pursue immunology as a major (Fig. 6A). However, a significant correlation was observed between the timing of a personal experience and the selection of immunology as a major, such that an introduction to immunology through a personal experience later in life (teen or young adult years) had a positive correlation with the selection of immunology as a major. In contrast, introduction to immunology through a personal experience earlier in life (elementary school and adolescent years) negatively correlated with the selection of immunology as a major (Fig. 6B).

Of the undergraduate respondents reporting that they were introduced to immunology through a personal experience, the majority of nonimmunology majors reported that their personal experience involved “vaccination/allergies/other immune-related issues,” whereas immunology majors more frequently reported being introduced because of a “family/friend with an immunology-related disease” (Fig. 7A). Within the graduate student population, equal numbers of immunology majors and nonmajors reported having a personal experience that involved a “family/friend with an immunology-related disease,” whereas more nonimmunology students reported an experience that involved “vaccination/allergies/other immune-related issues” (Fig. 7B).

Although a number of correlations have been identified that may provide insight into key factors that drive decision making, a primary goal of this study was to identify which type of experience was perceived as the most influential by students in the selection of a major. When immunology majors were asked, “What was most influential in your decision to study or pursue immunology as a career?” they reported that an educational experience was more influential than a personal experience in their choice of an academic discipline (Fig. 8). This was observed at both undergraduate and graduate levels.

Together, these data provide insight into the type and timing of the introduction to the immunology experience that may influence a student’s decision to pursue immunology academically, but also highlight the interrelatedness and complexity of the influencing factors.

DISCUSSION

As STEM employment grows exponentially, there is a vital need to understand the factors that influence students to pursue a degree in a STEM field (18). Immunology is inherently interdisciplinary, benefiting from and exhibiting the cross-fertilization of knowledge and skills from other areas in STEM. Immunology also has tremendous relevance to address a range of critical issues that impact the health of the population globally. The purpose of this study was to identify factors that may persuade students to select immunology as a college or postsecondary major. The findings from this study suggest that educational experiences have a greater influence on a student’s selection of immunology as a major than do personal experiences, but the data also demonstrate that the timing of the introduction to immunology may be a key factor as well.

The majority of both nonimmunology and immunology students reported being introduced to immunological concepts in an academic setting (Fig. 2). There are many activities that constitute an educational experience, and all of them can have a critical impact on choices that students make. Certainly, students are unlikely to develop appropriate science or discipline-specific knowledge without being given effective instruction and experiences (20, 21). However, the method by which the instruction is given can be very influential with regard to a student’s interest in a topic, which was highlighted by some comments regarding how the complexity of immunology was approached in the undergraduate classes that graduate students took, as described during the one-on-one interviews. The type of learning activity selected to teach a science topic, the way in which a topic is taught (22), and the perceived enjoyment and confidence of the teacher teaching the topic (23) can all influence a student’s interest in the topic.

As shown in Fig. 4, many students identified that they were initially exposed to immunological concepts by participating in a unit/learning activity. The inability to categorize the educational experiences reported by respondents as positive or negative is a shortcoming of this study. Furthermore, the survey did not specifically ask in what class the unit/learning activity occurred. However, based on information gathered from the interviews with graduate students, it is likely that some of these experiences occurred in introductory biology courses. Introductory science courses are often gateway courses to a variety of STEM fields and excitingly, a variety of studies have been

**FIGURE 6.** Both immunology majors and nonmajors report being introduced to immunology through a personal experience. (A) Frequency of respondents who reported either being introduced to immunology through a personal experience or not. (B) Timing at which students were exposed to immunology by a personal experience. \( \chi^2 \) analysis; *\( p < 0.05 \). ns, not significant.
recently published on strategies to improve learning in STEM disciplines in an effort to promote student retention among these disciplines (24, 25). In 2012, the President’s Council of Advisors on Science and Technology presented strategies to improve STEM education during the first 2 years of college. The President’s Council of Advisors on Science and Technology reports that <40% of students in the United States entering a STEM major graduate with their intended degree (26), and an even lower completion rate is observed in underrepresented student populations (27). In this study, we did not conduct analyses to determine whether the pursuit of an immunology degree is correlated with race/ethnicity. However, this is an important aspect to investigate and is a component of our long-term study, which will expand on the findings presented in this study.

Another key finding that arose from the data was the correlation between the timing of the experience that introduced students to concepts in immunology and their desire to pursue immunology academically. For graduate students who were introduced through an educational experience, there was a negative correlation between an introduction to immunology in high school and a decision to pursue immunology, whereas an introduction later in life (in college) positively correlated with the desire to pursue immunology in graduate school (Fig. 3C). One possible explanation for these correlations is the type of educational experience. Historically, training in immunology has largely been done at the graduate level. Only a few institutions in the nation offer an immunology-intensive undergraduate curriculum (28), and rarely are courses in immunology available in high school curricula. Often, the ability of educators to teach the material competently in a manner that is level-appropriate and engaging is a driving force in stimulating the interest of a student in a particular subject. When concepts are introduced in very short time frames, such as a unit or learning activity, the quality of the presentation is likely even more critical. Personal communications with high school teachers suggest that even in classes such as anatomy and physiology, where teachers feel confident about teaching organ systems in the body, they struggle to understand the immune system themselves and thus struggle to explain it well to students.

Although we were unable to get feedback from undergraduates through interviews, as a result of a number of factors beyond our control, we were able to conduct short interviews with graduate immunology and nonimmunology students, which provided additional insights into influential factors that impact the decision to pursue immunology. Feedback from graduate students was prioritized because that population of respondents alone had significant correlations between students pursuing immunology (or not) and the timing of the introduction through an educational experience (Fig. 3C). Information gathered from these interviews demonstrated that graduate students currently pursuing immunology described having an undergraduate research experience (83%) and/or having a positive relationship with a mentor (62.5%) as factors that positively influenced their choice to pursue immunology (Fig. 5). A limitation of our survey was the use of “internship” alone without the inclusion of the word “research.” However, both

FIGURE 7. Types of personal experience reported by respondents. Responses from (A) undergraduate or (B) graduate students.
undergraduate and graduate students reported “research” in the “other” category when asked about the type of educational experience. Furthermore, “research” was listed as a method of being exposed to immunology when students selected “no” for both an introduction through an educational experience and a personal experience. The fact that research experience and positive mentor experiences were the top influential factors is not surprising given the impact of research experiences and faculty mentors on a student’s understanding of the field, interest in the subject, and positive student development (29–32).

Equally important as the presentation of information by an educator is the readiness of the student to process the information that is presented. Indeed, students need a certain level of career maturity to appropriately evaluate options and to select a profession (33). The career maturity of a student is an assessment of that individual’s biological, social, and psychological preparedness to make an appropriate decision about choice of profession (34, 35). Studies have demonstrated that students who have a higher level of career maturity make career choices that afford them better success, whereas students with a lower level of career maturity more often feel unsuccessful or inadequate (36–38). Perhaps the required level of career maturity needed by students to make an informed career decision parallels a level of maturity needed to appreciate the complexity of immunology that will facilitate an introduction to the discipline being viewed positively. The findings from this survey pertaining to the timing of personal experiences provide further support, such that an introduction to immunology through a personal experience in the teen or young adult years had a positive correlation with the selection of immunology as a major, whereas a personal experience earlier in life (elementary school and adolescent years) negatively correlated with the selection of immunology as a major (Fig. 6B). These findings suggest that, when individuals are exposed to a complex scientific discipline, like immunology, through either an educational or personal experience, their relative level of maturity and ability to effectively process the experience may be critical factors.

Interestingly, however, graduate students pursuing immunology who participated in the personal interviews expressed a desire to have been introduced to immunology sooner, stating: “I wish I had had more exposure early on, like in high school and stuff like that”; “I really wish that I had been exposed to immunology sooner, so that I could have more of a background when I came here and started my training”; and “I felt like immunology was something that wasn’t well discussed. Like, I feel like most other themes that you have an option of studying in graduate school, you’re introduced to either personally or academically, prior to college. And I felt like immunology was not.” The ability to distribute this survey more broadly likely would have provided additional insight regarding the factors influencing the decision of graduate students to pursue immunology.

Findings from this study reveal the multiple layers of influential experiences involved in a student’s choice to pursue an academic discipline, including both intrinsic and extrinsic factors. The purpose of this study was to identify experiences that influence the desire to pursue the field of immunology and to potentially harness these insights to create optimal educational interventions that will lead more students to pursue either an undergraduate or graduate degree in immunology. Our findings support the conclusion that the introduction to immunology through an educational experience has more potential to influence decision making than does exposure through a personal experience. Moreover, we found that more graduate students wished that they were introduced to immunology earlier in their career. Despite efforts, such as the American Association of Immunologists Summer Research Program for Teachers (https://www.aai.org/Education/Summer-Teachers), to increase immunology education at the high school level, few opportunities exist. Currently, there are only a few high school courses that offer some introductory immunology content, such as AP Biology and Anatomy and Physiology, but unfortunately, not all students interested in science will enroll in these classes. Also, many high school curricula lack standardized, age-appropriate immunology-related content, thereby failing to effectively engage students interested in immunology at an early point in their educational progression. To effectively encourage more students to pursue an immunology major at the undergraduate and graduate level, this study suggests that immunology needs to be integrated into standardized high school biology curricula. In addition, efforts may need to be undertaken to ensure that educators at the high school level, as well as at the undergraduate level, have the appropriate proficiency to teach immunology in an effective manner that allows students to better understand the complex, interrelated concepts that are germane to the immune system. Collectively, these data provide insights that may help inform the development of immunology curricula with an effort to actively engage more students who will ultimately pursue a career in immunology.

DISCLOSURES

The authors have no financial conflicts of interest.

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