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Science Scholars: Integrating Scientific Research Into Undergraduate Medical Education Through a Comprehensive Student-Led Preclinical Elective

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Abstract

Introduction: One of the goals of evidence-based medical education is to familiarize future health care practitioners with the scientific method so they can interpret scholarly literature and communicate appropriately with patients. However, many students lack the skills necessary to conduct research themselves. We describe a preclinical elective course designed to equip students with these skills through workshops, mentorship, and research experience. **Methods:** Through an application process, we selected first-year medical (M1) students who expressed interest in conducting basic, translational, or clinical research. Throughout the yearlong curriculum, students attended a series of 10 1-hour workshops to learn the skills necessary to engage in research. Additionally, each student was paired with a peer mentor. As their final project, students completed a specific aims page based on their projected research study. **Results:** Over the course of 3 years, 96% of students secured a research position for the summer following M1, and 36% secured positions at external institutions with nationally competitive funding, compared to 10% of their peers who did not participate in the elective. Of students, 80% indicated that this elective helped them find and secure these research positions, and 75% of students reported that they learned valuable skills not taught in their medical curriculum. **Discussion:** Participation in a preclinical research elective can provide immediate value in the form of research skills with the prospect of stimulating a lifelong interest in scientific inquiry. Our curriculum was delivered in a medical school setting, however it is applicable to any health care professional school.

Keywords
Preclinical, Mentoring, Physician-Scientist, Career Choice, Evidence-Based Medicine, Translational Research

Educational Objectives

By the end of this yearlong curriculum, students will be able to:

1. Design and propose a research study including literature review, formulation of a hypothesis, and completion of a research proposal.
2. Communicate scientific research results in both written and oral form, including basic statistical analyses and data visualization.
3. Apply for a funded position in clinical, translational, or basic research during the summer between the first and second years of medical school.
4. Articulate the advantages and practical implications of incorporating research in their future careers.

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Introduction

Physician-scientists, about half of whom are physicians without a PhD, are essential for the advancement of medicine through biomedical and translational research. While medical education aims to familiarize future physicians with evidence-based knowledge and approaches, medical curricula in general are not structured to produce actively engaged scientists and therefore, medical trainees are often insufficiently prepared for writing scientific papers and grant proposals, presenting data, and communicating science.[1] This lack of educational emphasis and mentoring opportunities has translated into a trend towards the inevitable decline in the physician-scientist workforce. Between 2003 and 2012, the number of physician-scientists under the age of 60 declined, while the number of those aged 61 or older increased.[2,3] This indicates a need for increasing the emphasis on scientific education for physicians-in-training and those interested in research.

Additionally, research experience in medical school has been shown to predict greater career achievement in academic medicine.[4] According to one study, students with extracurricular research experience during medical school published more research articles (four on average) after graduation compared to those without such experience (one on average).[5] However, students who attempt to engage in research activities on their own often cite encountering obstacles, such as perceived lack of research opportunities and "not asking the right people."[6] These needs may be addressed with structured curricula complemented by mentorship programs, which have the potential to provide students with guidance and, as a result, lead to increase in research productivity, improved medical school performance, and higher sense of wellbeing overall.[7,8]

Despite this need for more educational opportunities dedicated to developing medical students' research skills, medical school curricula rarely offer programs for the systematic development of skills necessary for active participation in research beyond occasional sessions dedicated to reading and understanding scientific literature. A recent systematic review of academic literature describing elective courses for medical students during the preclinical curriculum[9] revealed that of the 37 electives identified, only one[10] aimed to improve students' research skills, specifically scholarly communication. Other educational efforts in medical education have focused on developing research skills in various forms, such as individual in-person workshops[11] and self-directed curricula,[12] some of which are completed online.[13] These programs, however, are inevitably limited in scope due to their short-term nature and lack of the crucial mentorship element. Moreover, with the recent general trend among medical schools to move towards an integrated preclinical curriculum, even less space remains devoted to foundational science. To our knowledge, a longitudinal curriculum focusing on a variety of research-related skills combined with personal mentoring and culminating in hands-on research experience has not yet been described in the literature.

In order to address this need, we designed the Science Scholars curriculum for first-year medical (M1) students at our institution. This scholarly research training served two main functions. The first was to provide students the necessary basic skills to be able to devise, conduct, and communicate their own research. The second was to help M1 students find and obtain funded research positions during the summer between their first and second years of medical school. The curriculum fulfilled these functions by enrolling a selected group of students into a yearlong preclinical enrichment elective course consisting of a series of educational workshops complemented by an individualized mentorship structure and concluded with hands-on research experience. Our presentation of this Science Scholars Curriculum at several national conferences generated significant interest among medical educators. Our hope in sharing this work here is to facilitate implementation of this curriculum at other institutions.

Methods

This program was designed and coordinated by MD-PhD students, usually two to three student leaders each year, as they represent the natural liaison between the medical and graduate programs at our institution. At the beginning of each academic year, we presented the Science Scholars curriculum to all M1 students during their orientation activities as an enrichment elective (Appendix A). M1 students interested in incorporating research activities into their future medical careers subsequently applied to the course by submitting the online Science Scholars application form (Appendix B).

As the course coordinators, we selected 10-14 medical students to participate in the yearlong enrichment elective course. The selection criteria for accepting students into the course were based on students' willingness to pursue a research experience during the summer between the first and second years of medical school and their overall motivation for incorporating research activities into their long-term career plans. Notably, prior research experience was neither necessary, nor disqualifying. Timely submission of the application and completeness of students' responses were additional criteria used for selection. Over the 3 years, on average 81% of the students who applied were selected to participate in the curriculum. The students who were not admitted to the program, while not taking part formally, were still allowed to attend the workshops, which were always publicly announced.

The yearlong course consisted of four parts: class-based sessions, mentorship meetings, a final project, and a summer research experience (Figure 1). In order to pass the course and obtain a record on their medical school transcripts for completion of the enrichment elective, the students were required to attend at least 80% of the scheduled sessions, meet with their peer mentors approximately once per month, and present their final projects to the group. Students who were only one session away from satisfying the session attendance requirement were given the opportunity to rectify by writing an essay of at least 500 words with the following prompt: "What are the features of

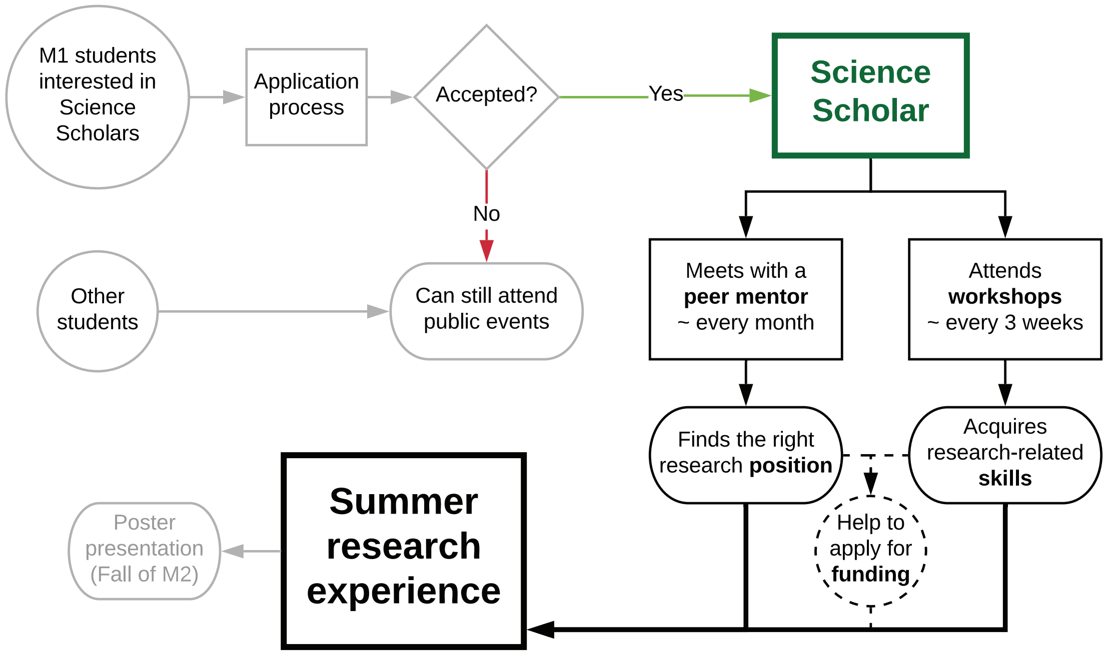

Figure 1. Science Scholars curriculum participation timeline. First-year (M1) students selected to become Science Scholars attended sessions and met with their assigned mentors in order to attain the skills necessary to pursue their summer research experience. Second-year (M2) students were expected to present their research to their peers. The workshops were accessible to be attended by all medical students.

successful physician scientists? With that in mind, how will you strive to achieve your career goals?"

Sessions

A core aspect of the yearly curriculum consisted of 13 scheduled sessions with the composition further described below. While some sessions should understandably take place in a specific order (for example, the matching ceremony being first and final presentations last), most sessions can be presented in any order based on faculty or staff availability specific to a given institution. Events in this curriculum were spaced out throughout the year in order to avoid overburdening the M1 students' schedules. A sample yearly schedule with further comments on the order of events and their timing is provided in Appendix C. Attendance was taken at each session.

Matching ceremony: Newly admitted scholars were ceremoniously welcomed to the program by the coordinators, faculty advisors, and the dean of the medical school. After a welcome and short presentation describing the structure of the program, the requirements for passing, and the schedule of the upcoming workshops, scholars' names were read one by one along with those of their mentors. The rest of this session was spent meeting and socializing with each other as well as their mentors, if present. In case of the mentor's absence, contact information was provided to the respective scholar to establish communication with them.

Poster presentation night: This widely publicized yearly event featured the previous year's scholars presenting their summer research. The format was that of a typical conference poster session and all medical school and undergraduate students and faculty were welcome to attend. Attendance was mandatory for the current year's scholars in order to learn about the research opportunities available at our institution.

Workshops: Each year, 10 1-hour interactive sessions served to introduce students to key scientific research skills in order to prepare them for their upcoming summer research experience. Over the course of the 3 years this curriculum was offered, we presented workshops on 16 different topics—some core topics were presented every year, while others were modified or added (as indicated by the superscripts in Table 1) based on student feedback. Materials for 10 of the sessions can be found in Appendices D-O, which can be implemented to reproduce a full year of the Science Scholars curriculum.

Several core topics were covered in the workshops every year. For example, students were trained in writing a specific aims page (Appendix D), which was necessary for completion of

Table 1. Workshops Presented Over 3 Years of the Science Scholars Curriculum

Workshop Title	Abbreviations	Learning Objectives
Writing the Specific Aims Page (Appendix D)	Specific aims	At the end of the 1-hour session, students were able to: Discuss the National Institute of Health grant review process. Construct an overall narrative for one's grant. Write the specific aims page, including all the necessary components.
External Funding and Scholarships (Appendix E)	Funding	At the end of the 1-hour session, students were able to: Navigate some of the available funding resources. Apply for awards, scholarships, and fellowships for the upcoming summer. Describe the application timeline and the steps necessary for a successful submission.
Clinical Trials and Design (Appendix F)	Trials	At the end of the 1-hour session, students were able to: Explain the basics of drug development. Discuss the differences between various phases of clinical trials. Describe clinical trial oversight and ethical considerations.
Research Career in Medicine Panel (Appendix G)	Panel	At the end of the 1-hour session, students were able to: Discuss the role of research in medicine through a discussion with physician-scientists. Describe the advantages and challenges of balancing a career in research and medicine.
How to Effectively Read Scientific Literature[a] (Appendix H)	Literature	At the end of the 1-hour session, students were able to: Select the appropriate resources for biomedical research literature. Review and scan relevant content in original sources. Interpret figures and tables.
Finding and Managing Scientific Resources[a]	Resources	At the end of the 1-hour session, students were able to: Work with scientific search engines (e.g., PubMed). Use some of the common reference managers. Follow scientific literature on specific topics.
Data Processing and Visualization in R[a]	Visualization	At the end of the one-hour session, students were able to: Describe what R is and what it is used for. Use some of the common R statistical packages for data analysis. Visualize data analyzed in R.
Metrics: Managing Personal, Journal, and Article Impact[a] (Appendices I & J)	Metrics	At the end of the 1-hour session, students were able to: Discuss impact metrics, what they measure, and their importance. Find tools to determine these metrics. Discuss the best practices for optimizing measurement of one's research impact.
Applied Statistics in Medicine[a]	Statistics	At the end of the 1-hour session, students were able to: Conduct analysis of survival and longitudinal clinical data. Discuss common statistical considerations for randomized clinical trials
PubMed: Tips and Tricks[a]	PubMed	At the end of the 1-hour session, students were able to: Use the basic and advanced features of PubMed, including efficient searching, getting full access to articles, etc. Search PubMed for the purposes of their own research project using the skills learned.
How to do a Literature Review[b] (Appendix K)	Literature	At the end of the 1-hour session, students were able to: Select a subject-specific article database and an interdisciplinary database appropriate for their review question. Create a concept table based on their question. Describe the function of citation managers. Differentiate between strategies used for a quick look-up and a comprehensive literature search.
Clinical Resources Overview[b] (Appendix L)	Resources	At the end of the 1-hour session, students were able to: Select best clinical resources for different question types. Use advanced features of clinical resources. Describe red flags for unreliable resources.
Data Visualization in Tableau[b] (Appendices M & N)	Visualization	At the end of the 1-hour session, students were able to: Use most of the basic functions of the Tableau software. Create both effective and esthetically pleasing data visualizations using Tableau.
Student Mentorship Panel (Q&A)[b] (Appendix O)	Q&A	At the end of the 1-hour session, students were able to: Discuss various options for integrating research into one's medical education. Discuss the advantages and challenges of conducting research from the perspective of a medical student or a resident.
Best Practices in Data Visualization[b]	Best practices	At the end of the 1-hour session, students were able to: Explain the basic principles of visualizing data in an understandable manner. Recognize good and bad data visualizations from examples.
Formulating a Hypothesis[b]	Hypothesis	At the end of the 1-hour session, students were able to: Discuss the best practices in (null) hypothesis formulation and testing. Distinguish concepts such as sensitivity versus specificity, study power, result significance, etc. Discuss the difference between exploratory data analysis and hypothesis-driven studies.

[a]Offered in 2017-2018 only.
[b]Not offered in 2017-2018.

the final project, while the External Funding and Scholarships workshop presented funding opportunities available to students for their upcoming summer research activities and advised students on how and when to apply for them (Appendix E). Other workshop topics were included based on availability of the respective faculty members.

With the exception of the External Funding and Scholarships workshop (which was taught by the MD-PhD student curriculum coordinators) and Student Mentorship Panel, workshops were taught by the faculty members at our institution, who were all chosen for their expertise in the given subject area. Each lecturer who agreed to deliver a workshop on a given topic was provided with a list of specific session learning objectives (Table 1), which aimed to make the workshops interactive with hands-on exercises and lively discussions.

Working closely with the student affairs administration at our institution, we typically scheduled the workshops in the afternoons to avoid scheduling conflicts with the core M1 medical courses. While attendance was recorded for Science Scholars enrollees, these workshops were accessible to be attended by all medical students. In the Spring 2020 academic term, given the COVID-19 pandemic, these interactive small-group sessions were seamlessly converted to a remote, video-conferencing format without a significant impact on the students' ability to attain the intended learning objectives.

Final presentations: Each student had up to 4 minutes to present and answer questions about their final project. Students delivered an oral presentation, essentially an elevator pitch, of their research project proposed for the upcoming summer. The presentation was verbal and could be accompanied by slides. This session concluded the curriculum for the year.

Mentorship

At the beginning of the academic year, we recruited peer mentors from among MD-PhD and PhD students at our institution, as well as medical students who had previously completed this course (Science Scholars alumni). Individuals interested in becoming peer mentors completed the online mentor signup form (Appendix P). After selecting the student participants (science scholars), as described above, we matched each of them with one peer mentor based on mutual research interests whenever possible. A perfect match was not deemed necessary, as peer mentors were intended to serve as general guides for navigating the research environment at our, as well as other, institutions. We instructed peer mentors to use their past personal experience to assist students by helping them connect with faculty members engaged in research activities, discussing ways in which students might incorporate research activities into their medical career, and helping students prepare for their upcoming summer research experiences. We asked students to schedule one-on-one meetings with their assigned mentors according to their mutual availability. We instructed students to fill out their mentorship logs online after each meeting with their peer mentors so that we would receive immediate feedback on the quality and frequency of their mentorship encounters (Appendix Q). At the end of the academic year, each peer mentor received a $20 Amazon gift card as an expression of our appreciation.

Final Project

While students were not required to complete any assignments during the year, they were required to submit a National Institute of Health grant-style specific aims page based on the research project they anticipated working on during the upcoming summer. For this purpose, one of the workshops offered every year (Appendix D, Writing the Specific Aims Page) served as a broad introduction to grant writing with a focus on the compilation of the specific aims page. The final project was due at least 2 weeks before the final session, during which time the curriculum coordinators gave students written feedback in order to be able to implement any changes for the oral presentation. A 4-minute presentation of their project during the last course session of the year served as a conclusion of the course.

Research Experience

All students were required to pursue a research experience during the summer between their first and second years. This experience could be in basic, translational, or clinical research, and students were encouraged to apply for nationally competitive funding awards, which was the focus of one of the workshops (Appendix E, External Funding and Scholarships) offered every year. In addition, after completion of the summer research experience, all students were expected to present the work and results from their experience to the wider community at our institution (including next year's scholars) in the fall academic term of their M2. This gave students the opportunity to scientifically engage with members of the research community, receive feedback on their work, and inspire the next cohort of scholars for their own upcoming research endeavors.

Evaluation

The outcomes of the Science Scholars curriculum were evaluated by using feedback surveys. An online feedback survey, consisting of two parts, was distributed to all students who completed the course at the end of the year. The first part of the survey (mentorship evaluation) asked students to reflect on the mentorship component of the curriculum and assess both the quality and value of the personal mentorship they received (Appendix R). This valuable feedback was also to be taken into consideration when reinviting individual peer mentors to participate in Science Scholars in the future. Therefore, this part of the survey was not anonymous. The second part of the survey was separate from the first, was completely anonymous, and asked students to evaluate and reflect on the curriculum with regards to each of the workshops offered, the final project, and its overall organization (Appendix S). Starting with the second installment of the curriculum (2018-2019), we asked students to provide their feedback on each individual workshop within a week of its occurrence in order to receive more accurate responses (Appendix T).

Results

Over the 3 years that this curriculum was implemented, the passing requirements were satisfied by 92% of students, or 35 out of 38 who enrolled (9 out of 10 in 2017-2018, 12 out of 14 in 2018-2019, and all 14 in 2019-2020; Table 2). Of those who completed the course, the mentorship survey was completed by 31 students, while the anonymous part of the survey had a response from between 22 and 25 students on each of the questions.

Mentorship Survey

Mentoring quality: The overall feedback about the mentorship component of the Science Scholars curriculum was overwhelmingly positive, repeatedly highlighting the importance of peer mentorship. This was exemplified by the following quotes, in which students described the positive aspects of their relationship with their peer mentors:

- "My mentor was a fellow medical student. He is also interested in the same field as I am. This made his guidance extremely helpful, since he was extremely knowledgeable about the subject."
- "[My mentor] was very willing to look over my application materials and to talk through my research plans. I also really appreciated her perspective on these matters because she was not afraid to tell me what she thought was an unrealistic expectation or an unlikely opportunity."
- "My mentor has been super open and honest with me which has been very nice."

As we had hoped, others appreciated their mentors' insight into the research community at our institution and beyond:

- "[My mentor] gave me some names in research who I could contact."
- "My mentor gave me some valuable insight as to how to seek research opportunities within the Geisel community. As an MD-PhD student he was super experienced about how to navigate the basic science world and I think that was super valuable."
- "Very enthusiastic and knowledgeable about the research process. Helped very much in looking into [Principle Investigators] to work with."
- "My mentor was also helpful in navigating the process of applying for external grants and reading drafts/preparing grant proposals."
- "[My mentor] knew the available investigators, their personalities, and their projects very well, so in that sense was an excellent match. [He] listened carefully to my interests and goals and responded with helpful suggestions of who to meet."

When asked about their negative experiences, 15 out of the 31 responding students (48%) did not report any. Those who did report negative experiences cited low frequency of meetings due to unavailability (that of the student, peer mentor, or both) or mismatch in their research interests. There were no alarming concerns raised in this survey. When asked whether they were satisfied with their peer mentors overall, almost all students (90%) agreed that they were satisfied and indicated that they would recommend their mentor to be asked to provide their mentorship again in the future. Several of the students emphasized that mentorship was an integral part of their experience in the Science Scholars curriculum.

Frequency of mentoring encounters: All students were encouraged to meet with their mentors once per month, amounting to six to seven mentorship meetings for the academic year. However, successful completion of the course was not conditioned on any specific minimal number of meetings. On average, students met with their mentors roughly four times over this period, ranging from one to nine meetings. When asked to reflect on the desired frequency of their mentorship meetings as compared to how many times they actually met with their peer mentors, 39% of the students indicated that they wished to have met with their mentors more than they did, while 58% of them were satisfied with their meeting frequency, and only one student (3%) wished to have met with their peer mentor fewer times.

Table 2. Summary of Quantitative Results From Feedback Surveys Over the 3 Years of the Science Scholars Curriculum

Survey and Question	2017-2018[a]	2018-2019[a]	2019-2020[a]	Overall[a,b]
Curriculum completion rate	90%	86%	100%	92%
n	10	14	14	
Mentorship survey				
How and how many times did you meet with your peer mentor? Select all that apply.[c]				
In person	2.6	2.5	2.5	2.5
Video call	0.0	0.0	0.0	0.0
Phone call	1.1	0.5	1.8	1.1
Total	3.7	3.0	4.3	3.6
n	9	12	10	
Originally, you would have met with your peer mentor… .[d]				
More often	56%	33%	30%	39%
About the same	33%	67%	70%	58%
Less often	11%	0%	0%	3%
n	9	12	10	
Would you recommend this mentor to be a peer mentor for Science Scholars in the future years again?[d]				
Yes	89%	100%	80%	90%
No	0%	0%	20%	6%
Not sure	11%	0%	0%	3%
n	9	12	10	
Anonymous survey				
Did you find a research position or experience for the upcoming summer?[d]				
Yes	100%	88%	100%	96%
No	0%	0%	0%	0%
Not sure	0%	13%	0%	4%
n	9	8	8	
Were you able to obtain research funding (fellowship award, scholarship, etc.) for the upcoming summer?[d]				
Yes	44%	38%	25%	36%
No	44%	63%	75%	60%
Not sure	11%	0%	0%	4%
n	9	8	8	
What role did the Science Scholars curriculum play in your search (successful or not) for a research position and/or funding? Select all that apply.[e]				
None at all	22%	0%	38%	20%
I learned about it in the External Funding and Scholarships workshop.	56%	38%	13%	36%
I was motivated to look for it by the Science Scholars curriculum.	56%	63%	38%	52%
My peer mentor helped me.	22%	38%	38%	32%
Another Science Scholar helped me.	0%	13%	13%	8%
Other	11%	25%	13%	16%
n	9	8	8	
In the following questions, indicate whether you strongly disagree (1), disagree (2), are neutral (3), agree (4), or strongly agree (5).[c]				
In this elective, I learned skills I would not have otherwise learned in the medical school curriculum.	3.6	4.3	4.0	4.0
n	8	8	8	
This elective met my learning needs in this area of study.	4.2	4.0	4.0	4.1
n	6	8	8	
The objectives were well defined and clearly presented.	4.0	3.9	3.9	3.9
n	6	8	8	
The instructor(s) was engaging and enthusiastic.	3.7	4.3	4.5	4.2
n	6	8	8	
I enjoyed learning in this elective.	4.0	4.4	4.0	4.1
n	6	8	8	
The required work was:[d]				
Too much	0%	0%	0%	0%
Too little	0%	0%	13%	5%
The right amount	100%	100%	88%	95%
n	6	8	8	
The time investment required was:[d]				
Too much	0%	0%	13%	5%
Too little	0%	0%	13%	5%
The right amount	100%	100%	75%	91%
n	6	8	8	
Rate your overall evaluation of this elective.[d]				
Poor	0%	0%	0%	0%
Fair	0%	13%	13%	9%

(*Table Continues*)

Table 2. (*Continued*)

Survey and Question	2017-2018[a]	2018-2019[a]	2019-2020[a]	Overall[a,b]
Good	50%	25%	38%	36%
Very good	17%	38%	25%	27%
Excellent	33%	25%	25%	27%
n	6	8	8	
If asked about the value of this elective by another student, I would:[d]				
Not recommend	0%	0%	0%	0%
Recommend	100%	63%	75%	77%
Enthusiastically recommend	0%	38%	25%	23%
n	6	8	8	

[a]Percentages may not total exactly to 100% due to rounding.
[b]Overall scores are weighted averages of the results from each year.
[c]Averages reported.
[d]Multiple-choice question; percentages reported.
[e]Percentages reported.

Anonymous Survey

Research positions and funding: In the second, anonymous part of the feedback survey, we assessed the overall effectiveness of the Science Scholars curriculum with respect to its nonmentorship components. Almost all of the survey respondents (96%) were able to secure a research experience position for the upcoming summer, 36% of the students were able to obtain a nationally competitive source of funding, and the same proportion were able to secure a position away from our institution. Students who were still waiting to hear back about their applications were allowed to reply *not sure*; 4% of students selected this option. When asked about the role of the course in their search for the summer positions and funding awards, 52% indicated that they were motivated by the Science Scholars curriculum, 36% of the students learned about their specific research position or funding in the External Funding and Scholarships workshop, and 32% of the students were helped by their peer mentor. Only 20% indicated that the course did not play any role at all in securing their summer research position.

Workshop assessments: When asked to assess the usefulness of the workshops on the scale of 1-5 (1 = *not at all useful*, 2= *not sure*, 3 = *somewhat useful*, 4 = *very useful*, or 5 = *extremely useful*), the average score over the three years was 3.7 (or *very useful*). Each workshop was found to be *very useful* by at least some of the students in attendance (Figure 2), except for one, Finding and Managing Scientific Resources, which was later replaced by a more successful iteration, Clinical Resources Overview. Based on the feedback received after each year of the elective, we modified the topics and content of the workshops offered, and subsequently the average rating of the workshops steadily increased from 3.4 (in 2017-2018) to 3.8 (in 2018-2019), and finally to 3.9 (in 2019-2020). Remote delivery of some of the workshops in the spring 2020 academic term (Student Mentorship Panel Q&A, Data Visualization in Tableau, and Writing the Specific Aims Page) due to the COVID-19 pandemic did not negatively impact the workshop scores, as compared to the previous years.

Overall curriculum feedback: The Science Scholars curriculum was designed to complement and not compete with the core medical school curriculum, which represents 25 weekly hours of required coursework at our institution. On average, the Science Scholars curriculum represented an academic commitment of up to 1 hour per week split between the sessions (1 hour every 3 weeks), meeting with mentors (1 hour per month), and work on the final project. We surveyed how students perceived the volume of work that was required by the curriculum in the context of other academic responsibilities. The majority of students indicated that the required work (96%) as well as the time investment (91%) were "the right amount." Most of the students agreed that this course met their learning needs in this area of study (77%) and that they learned unique skills not taught in their medical curriculum (75%). On a scale capturing the overall evaluation of the course, (1 = *poor*, 5 = *excellent*), the overall score was 3.7 (or *very good*) and all the students would recommend the course to someone else, of which 23% would recommend it enthusiastically.

Discussion

In order to offer medical students an opportunity to gain research-related skills with hands-on experience, as well as facilitate and motivate their research involvement in their future careers, we designed the Science Scholars curriculum, implemented as an enrichment elective course at our institution. The format combined workshops and peer mentorship, both of which were highly valued by the participating students, and made this course a unique and complementary addition to the medical curriculum for those interested in active participation in academic medicine. We found that establishing this curriculum

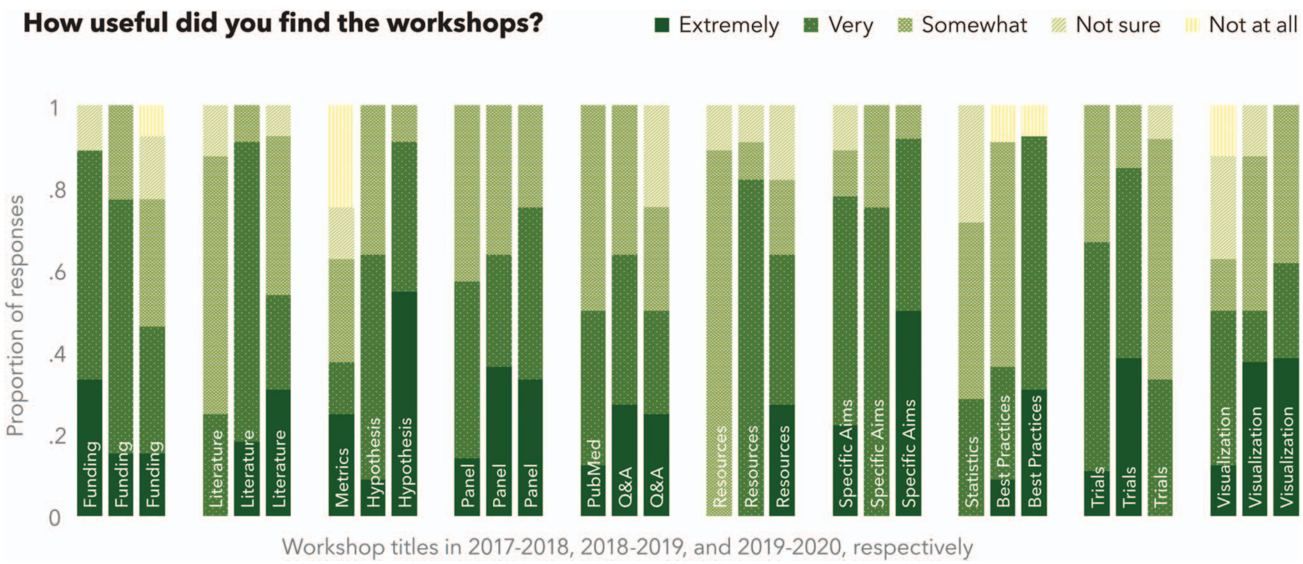

Figure 2. Self-reported usefulness of the workshops. Relative answer proportions for the 10 workshops offered each year, when students who attended them were asked to rate how useful they found each workshop on a scale of 1 to 5 (1 = *not at all useful*, 2 = *not sure*, 3 = *somewhat useful*, 4 = *very useful*, 5 = *extremely useful*). The workshop title abbreviations corresponded to those in Table 1; workshops that shared their abbreviation (such as How to Effectively Read Scientific Literature and How to do a Literature Review are both represented above as Literature in their respective years) are iterations of the same workshop with changed title and learning objectives as taught in the years indicated by the superscripts in Table 1. The Metrics, PubMed, and Statistics workshops from the first year (2017-2018) were replaced by the Hypothesis, Q&A, and Best Practices workshops, respectively, in the subsequent years (2018-2019, and 2019-2020). The overall subjective usefulness of the workshops improved between the years from the average score of 3.4 (2017-2018) to 3.8 (2018-2019), to 3.9 (2019-2020). The overall average score for all years combined was 3.7.

formally as an enrichment elective course for credit with an application process and a clearly defined set of requirements and expectations (as opposed to an open, informal interest group from years prior; data not shown) improved the attendance at the workshops as well as the overall engagement with the curriculum.

The success of the mentorship element seemed to be facilitated by the closeness in ranks, as the students and their peer mentors were usually only a few years apart in both their age and academic training. This allowed each student to be guided by a peer who could effectively inform their perspectives and expectations and do so in a nonthreatening, informal manner.

We found that receiving feedback soon after each workshop, rather than collectively at the end of the year, yielded much more detailed and likely more accurate feedback. The ratings of these workshops improved significantly over the years, possibly due to the adjustments made in response to the feedback. Discussion panels, with both senior physician-scientists and medical student peers, were among the most popular workshops offered, as students had a chance to have their questions answered in an interactive manner. Highly technical workshops, which required advanced knowledge of statistics or programming, were among the least well received and underwent modifications over the years. Specific examples of changes implemented in response to feedback included focusing on a graphic user interface-based data visualization tool (Tableau) instead of R, replacing a technical workshop focused on PubMed with a student mentorship panel, and focusing on more clinically relevant tools in the Resources workshop. Workshop ratings were not negatively impacted by remote delivery in the spring term of 2020 due to the COVID-19 pandemic.

Almost all of the Science Scholars curriculum students ended up participating in research during the summer between M1 and M2 and more than a third of them did so at external institutions, after undergoing a competitive selection process. Before the implementation of this curriculum in years 2012-2017, between 46%-57% of M1 students at our institution participated in summer research activities and this range increased to 64%-76% for summers following the years that the Science Scholars curriculum had been implemented (data obtained from the student affairs office at our institution), which corresponded to an attributable difference of at least six students per year. The high proportion of Science Scholars participating in summer research activities may indicate that we were simply successful at selecting those students through our application process. Given the difference in classwide proportions before and after implementation of this curriculum, however, the more likely explanation is that the

Science Scholars curriculum provided help finding and obtaining summer research positions to at least some of the students who would not have done so otherwise.

Among the greatest limitations of this curriculum were its organizational and logistical requirements. At our institution, the Science Scholars program has been actively coordinated by two to three MD-PhD students who each take on this role for about 2 years to dedicate their spare time during their PhD studies. These students regularly consulted a dedicated faculty member for advice regarding the curriculum development and administrative implementation. Besides the coordinators, additional volunteers were needed from among PhD, MD-PhD (usually also in the PhD phase of their studies), and senior MD students to serve as mentors. Additionally, faculty members need to be contacted yearly to schedule the workshops. The timing of events also needed to be consulted with the student affairs office in order to avoid scheduling conflicts with the regular M1 curriculum. Therefore, while the majority of the materials may be reused from year to year, active leadership to ensure quality curriculum delivery was required.

Given the decentralized nature of this curriculum consisting of multiple workshops each given by a different faculty member, with the exception of the final project, students did not receive any feedback on their work between the sessions. The longitudinal aspect of this curriculum was therefore captured primarily through students' interactions with their assigned mentors, who provided guidance and formative feedback throughout the year. All students who fulfilled the attendance requirements and submitted their final project passed the course and no other summative feedback was provided.

In the future, we are hoping that this curriculum may be more closely integrated with the regular M1 curriculum at our institution, possibly in the form of an honors track. While not all medical students may desire active involvement in scientific research, this curriculum would add significant value to their medical education experience with both immediate and long-term benefits. Formal integration with the medical curriculum would ensure that this important scientific way of thinking is seamlessly incorporated into the foundational science courses and save separate administrative time costs.

The Science Scholars curriculum prepared students for participation in clinical, translational, or basic research during their first summer at medical school, with anticipation that these skills and experiences will be further developed and utilized in their future careers as academic physicians. We believe that this curriculum can be implemented at other institutions to complement and enrich medical education for those who aspire to become academic physician-scientists.

Appendices

A. Intro Presentation.pptx
B. Application.docx
C. Sample Schedule.docx
D. WS Specific Aims.pptx
E. WS Funding.pptx
F. WS Clinical Trials.docx
G. WS Panel.docx
H. WS Scientific Literature.pptx
I. WS Metrics.pptx
J. WS Metrics Handout.docx
K. WS Literature Review.docx
L. WS Clinical Resources.docx
M. WS Visualization in Tableau.pptx
N. WS Visualization in Tableau Data folder
O. WS Q&A.docx
P. Mentor Sign-Up.docx
Q. Mentorship Encounters Log.docx
R. Mentorship Evaluation.docx
S. Anonymous Evaluation.docx
T. Workshop Feedback.docx

All appendices are peer reviewed as integral parts of the Original Publication.

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Prior Presentations

Kamal Y, Svoboda M, Pinto-Powell RC. Integrating scientific research into medical education through a comprehensive elective course. Poster presented at: Society of General Internal Medicine Annual Meeting; May 8, 2019; Washington, DC.

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Ethical Approval

Reported as not applicable.

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