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Building Undergraduate Life Science Research Skills Remotely, During and Beyond a Pandemic

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ABSTRACT: During the COVID-19 pandemic, undergraduate research experiences were deeply impacted–either canceled or pivoted to a range of remote experiences. In Summer 2020 and Spring 2021, we designed two rounds of remote programming aimed to build students' life science research skills and provide opportunities for mentoring and networking. Building skills, resumes, and connections in our students – many of whom are first-generation college students and/or from historically marginalized communities – are key to retention in the STEM "leaky pipeline." We created 33 online events including R workshops, journal clubs, and career panels featuring 25 alumni. Participants received a certificate of completion for their resumes and a letter of recommendation, which could be used to apply for future research experiences. Our program was non-selective, flexible, and accessible to all students, while being low-cost to our institution, allowing us to accommodate a sizeable number of students (87 total). This program serves a different purpose than summer internship programs, which are impactful and intensive experiences, but are highly selective and limited in capacity. Through this work, we gained insight into key features of this virtual programming, which could be adapted by other institutions seeking to design programming to prepare students to future undergraduate research experiences.

INTRODUCTION

In 2020, during the COVID-19 pandemic, one of the countless ways that undergraduate students were impacted was an inability to obtain hands-on undergrad research experiences. This deeply impacted not only students who may have already secured a research opportunity, but also students in earlier years of college who were in the process of building research skills in preparation for their first research opportunity (Carey et al., 2021; Erickson et al., 2022; Oliver et al., 2021).

Many undergraduate research programs for Summer 2020 were canceled entirely (Carey et al., 2021; Erickson et al., 2022). Other programs continued to run, but offered online professional development modules or remote synchronous cohort sessions, instead of independent research projects (Chin, 2020; Oliver et al., 2021; Vu et al., 2021). Programs maintaining independent student research projects took a wide variety of approaches to pivoting those projects during the pandemic. Two plant biology programs were able to have students do at-home data collection, in addition to using data from past years (Cridland et al., 2021; Jensen-Ryan et al., 2021). Some computational programs were able to keep the same projects planned pre-pandemic (Parrington and Giardino, 2021). Other programs changed from wet-lab projects to having students do dry-lab projects, write literature reviews, draft research proposals, or create open education resources such as podcasts (Berr et al., 2021; Boury et al., 2021; Michel et al., 2021). Some programs created opportunities for students to ask research questions through mining publicly available life science data sets, a strategy that has been used in coursework as well (Johnson and Knox, 2022; Thompson et al., 2020). And some programs used a combination of several of the above strategies to compensate for a lack of lab access (Johnson and Knox, 2022; Samad et al., 2021).

The pandemic exacerbated the struggles that many undergraduate students have in acquiring life science research experience during college, which is impactful because obtain-

ing undergraduate research experiences has been shown to be key for retention in the "leaky pipeline" of STEM (Chang et al., 2014; Graham et al, 2013; Jelks and Crain, 2020; Theobald et al., 2020). First-generation college students and students from historically marginalized communities are particularly impacted by issues affecting retention in STEM (Byars-Winston et al., 2015; Chang et al., 2014; Estrada et al., 2018; Graham et al, 2013; Jelks and Crain, 2020). These students benefit immensely from aspects of their undergraduate education that impact retention in STEM, including opportunities for active learning, personalized mentoring from mentors they can relate to, and building research skills (Byars-Winston et al., 2015; Estrada et al., 2018).

Even though colleges are now predominantly back to operating in-person, lab capacity issues continue to impact students' abilities to find these key undergraduate research experiences. Indeed, capacity issues for undergraduate life science research existed well before the pandemic. At some universities (such as the home institution of the authors, which is an R2 institution), there are a limited number of undergraduate research positions. There may be thousands of undergraduate students majoring in the life sciences looking for research experiences, but a small number of life science research groups on campus to accommodate them. Students seeking research opportunities can apply to summer programs such as Research Experiences for Undergraduates (REU) programs, but these programs receive large numbers of applications for small numbers of slots, oftentimes hundreds of applications for 10 or 15 slots (Barber et al., 2021; Chase et al., 2020; Corson et al., 2021; Johnson and Knox, 2022). This highly selective application process can favor students with prior research experience, which presents a particular challenge to any student seeking a first research experience. Selective application processes can favor students who can obtain multiple letters of recommendation from faculty who know them well, but this can be a challenge for students at universities with large science class sizes. Students without connections in their network may also have less polished resumes and personal statements because they do not have access to professional scientists to give them suggestions for editing those important documents (Jelks and Crain, 2020; Stephenson-Hunter et al, 2021).

In this study, we aimed to create flexible and accessible programming to build life science research skills and mentoring opportunities in students from all years of college and all levels of experience. We designed two rounds of remote programming (Summer 2020, and Spring 2021) aimed to build research skills, knowledge of career paths, and networking opportunities in undergraduate life science students at University of Massachusetts Boston, an R2 public university that is the most diverse school in New England, and the 3rd most diverse school in the United States (UMass Boston Office of Communications, 2020).

We intend to continue offering this virtual programming even though we have now returned to in-person operations. We found that the interactive virtual format fits well with the needs of students who are balancing their undergraduate studies with their daily commuting, and their employment schedules. Providing this programming during academic periods such as summer and spring break allows students to use these "gaps" in the traditional semester calendar to build research skills and mentoring that are essential to the career development of our students. We share the insights we gained from implementing this programming, which may be useful to other institutions seeking to develop flexible and accessible ways to prepare a wide range of their undergraduate students for future research experiences.

METHODS

The Students. UMass Boston is the most diverse school in New England and is the 3rd most diverse school in the country (UMass Boston Office of Communications, 2020). At UMass Boston, 66% are first-generation college students, 48% are Pell Grant recipients, and 58% speak a language other than English at home. Many of our students (48%) are from the city of Boston or nearby urban areas. In the UMass Boston student body, 54% of students are students of color (18% black or African American, 18% Hispanic/Latino, 3% two or more races, 15% Asian American) and 46% of students are white (UMB OIRAP, 2020; UMass PMS, 2021).

Recruitment of Student Participants. At the time of this study, there were 725 students in the Honors College. Of those, 240 students were life sciences students (which we defined as majors in biology, biochemistry, chemistry, exercise and health science, and environmental science). These 240 students were first informed via email about the possibility of a summer program, and were asked to complete an interest survey, which informed the design of our programming.

Once the program was established, Honors life science students were emailed a link to an Events Calendar (via Google sheets) in a weekly newsletter highlighting that week's events. The weekly newsletter was also sent to all life science majors at the university, and by targeted advertisement to other campus life science related groups, clubs and programs. All sessions were held via Zoom. Out of the 240 students we emailed about our programming, 87 total students took part in our events. This high rate of participation (36.3%) was striking given what our students were dealing with early on in the pandemic, including factors such as personal or family illness, working as health care workers (e.g. EMTs, CNAs, pharmacy technicians, etc.), and working as front-line workers (e.g. grocery stores, convenience stores, etc.).

Implementing Surveys. Students completed interest surveys before any programming began, for purposes of gathering input to impact program design. Students completed an event survey after attending each session, for purposes of program evaluation. Students registered for the R Workshops completed pre-workshop surveys and post-workshop surveys. In Fall 2022, students who completed either the Summer program or the Spring program (or both) were sent a follow-up survey. This study was deemed to have "Exempt" status (Protocol #3286) by the University of Massachusetts Boston IRB Committee. The wording of the questions in each survey is included in Appendix A. Surveys were administered via email using a link to a Google form. Survey data were entered into Excel for data storage and analysis.

At the end of the summer program, students who attended at least 12 sessions were asked to complete a self-reflection with the following prompt: "Write a 300-word personal reflection on what you learned & gained from the program."

R Workshops. R Workshops were held in both Summer 2020 and Spring 2021. These workshops were designed to train students in how to use the programming language "R" to do statistical analysis on large datasets, and to generate visualizations of data contained in those datasets. Before each session, students were emailed the full curriculum for the day, which they would read over in advance of the session. The curriculum was sent both as an RMD file (to download onto their computers in advance of the session, and use in R Studio) and as an HTML file (to read over in preparation) that is compatible with most web browsers to increase accessibility. The RMD file contained a series of blank sections to fill in with code (one section for each activity) with the instructions written as text in between each activity. During the sessions, students would have both Zoom and R Studio open on their computers. In R Studio, they would be doing the hands-on activities, which were laid out with full instructions in the RMD files. Students could go back into Zoom at any point to see the instructor and also the instructor's shared screen. The workshops were highly interactive, students could ask questions verbally or in the chat, and TAs were available for assistance in break-out rooms throughout the sessions. A Slack channel was available throughout the program for questions to the instructors.

The full curriculum is available on GitHub at: https://github.com/chfal/R_Workshop. The curriculum involves analyzing data about the prevalence of human diseases across the globe, and these data were obtained via GapMinder (www.gapminder.org/data/) and the Global Burden of Disease Study (IHME, 2020). GapMinder datasets were imported into R Studio as CSV files and were analyzed in R Studio using code the students wrote in R. Students visualized the Global Burden of Disease data using the free data visualization tools provided by GBD (IMHE, 2020).

RESULTS

Pre-Program Interest Surveys. Interest in the programming was assessed in Spring 2020 by emailing an interest survey to the 240 life science majors in the Honors College. A high response rate was obtained as 80 students replied to express interest in the program. Table 1 shows the 11 options we gave for the types of programming we could offer, and students could select multiple options. All 11 options received at least 31 (out of 80) votes (Table 1). Based on these results, we decided to offer many types of events, encompassing all options presented in the interest survey: alumni career panels, current student (near-peer) panels, journal clubs, one-on-one mentoring sessions, externally-organized scientific seminars, and R Workshops.

The program was designed to be flexible and accessible, and therefore students did not need to register in advance (with the exception of the R workshop), and students did not need to anticipate how many events or which events they intended to attend. They were allowed to participate regardless of the number of events they wanted to attend. We held events on all days of the week at a range of morning, afternoon, and evening times, to accommodate the most students despite their range of work schedules. If students decided at any point in the summer that they wanted a certificate of completion, then they needed to: attend at least 12 events by end of summer, fill out a short event survey about each event, and write a 300-word final self-reflection on their experience.

Program Participation and Event Surveys. A total of 63 students attended events during the summer (55 Honors College students, and eight non-Honors students). Of those, 34 students completed the program (31 Honors College students, and three non-Honors students) by attending and reflecting on at least 12 events. In total, we organized 33 events, held by 25 alumni of UMass Boston, and nine current UMass Boston students. A full list of events can be

Table 1. *Results of Interest Surveys Before Programming Began.*

Options selected in response to interest survey question "Which types of events might you be interested in? Select all that apply."	**# Students selecting this option** (n = 80)
Science career panels & alumni networking events	67
Overview and advice on the science grad school application process	67
Personal statement writing workshops	64
Scientific research seminars	60
Field trips (if possible, and if not, then virtual field trips)	59
Practice interview sessions (for med school, grad school, jobs, etc.)	58
Overview & advice on the med school application process	53
Resume writing workshops	47
Reading scientific papers	47
One-on-one mentoring sessions with alumni mentors	44
Statistical analysis	31

Table 2. *Breakdown of How Engaging and Informative the Students Found the Events.*

Please rate this event, based on how engaging and/or informative you found it	Number of students selecting this rating	
Extremely (converted to score of "5")	312	(56.0%)
Very (converted to score of "4")	187	(33.6%)
Somewhat (converted to score of "3")	55	(9.9%)
Not very (converted to score of "2")	2	(0.4%)
Not at all (converted to score of "1")	0	(0.0%)
No rating was selected	1	(0.2%)
Total number of event surveys	**557**	

found in Appendix B. In total, 557 event surveys were filled out across the 33 events we organized (Table 2).

In these 557 event surveys, students answered the question: "Please rate this event, based on how engaging and/or informative you found it" and options were: extremely (5), very (4), somewhat (3), not very (2), and not at all (1). Averaging the 557 event surveys gave an overall score of 4.46 (out of 5.0), and 89.6% of event surveys ranked the events either "extremely" or "very" engaging and/or informative (Table 2).

The qualitative data we obtained also spoke to the impact of the program. Each of the 34 students who completed the program responded to this prompt: "Write a 300-word personal reflection on what you learned & gained from the program." Representative student quotes are included in Table 3.

Many of the quotes discuss how the impact of the program came from their ability to directly relate to the speakers as alumni and current students, such as this quote:

> *This program has made me feel better knowing that these people were right in my shoes, but to hear different people showing me what they did with their time really made me look into different things after college. I'm not as stressed anymore because I feel like these panels and topics were exactly what I needed to listen to without realizing it at first. A lot of the information I learned was also something I feel like I wouldn't find elsewhere, and it helped that many people were asking great questions that I didn't think of.*

Other quotes talk about how students took specific and direct actions after attending program events that were steps towards securing undergraduate research positions, such as this quote:

> *Inspired by other students' experiences in how they got involved in research on campus, I emailed a few professors about joining their lab. Gladly, some of them responded. It was relieving to know that I can gain research experience in this manner.*

Table 3. *Student Quotes from Self-Reflection Essays.*

Student quotes in response to the self-reflection essay prompt: "Write a 300-word personal reflection on what you learned & gained from the program."
"As a first-generation college student, connections are hard to come by. What truly aided these growing fears and imposter syndrome were simply hearing the stories of others. The struggles and hardships that students faced and how they were still able to receive an acceptance towards a medical school. This was my specific reason for joining this career program. I knew that I would be able to hear the life of those before me and potentially rekindle why I am studying for endless hours and why I am willing to dedicate another decade towards education."
"This program taught me that it is alright to be confused, frustrated, and to still have this blocking fog. This way I can feel less anxious and stay motivated on my objectives. This message was insinuated throughout the whole program. I kept hearing synonyms like "it is not a race" or "enjoy the ride". There were also a few speakers who were either non-traditional (like me) or changed career paths due to experience. This was a wake-up call. I learned that life is not linear. Sometimes, deviation from the straight path is necessary to attain the same aim."
"I appreciated the paths they [speakers] had taken, which helped me gauge whether or not those career choices fit me. I loved hearing them discuss how they started and how indecisive they were, but they later settled and were happy to be doing something their passion laid on. Their indecisiveness and non-traditional paths reassured me that not everything is a straight path. There are bends and turns in career paths, and I should be ready to face and embrace every change that life brings."
"Because these students all attended UMass Boston at some point, their research experience helped broaden my knowledge of local opportunities."
"This program has made me feel better knowing that these people were right in my shoes, but to hear different people showing me what they did with their time really made me look into different things after college. I'm not as stressed anymore because I feel like these panels and topics were exactly what I needed to listen to without realizing it at first. A lot of the information I learned was also something I feel like I wouldn't find elsewhere, and it helped that many people were asking great questions that I didn't think of."
"Inspired by other students' experiences in how they got involved in research on campus, I emailed a few professors about joining their lab. Gladly, some of them responded. It was relieving to know that I can gain research experience in this manner rather than applying to competitive research programs around the country."

After the panels, students also often reached out asking for follow-up meetings with alumni presenters, who made themselves available so that students could expand their mentoring networks.

Because there were many different types of programming offered throughout the summer, in Table 4, we parse out the evaluation data by each type of session: alumni career panels (16 events), current student panels (seven events), journal clubs (four events), one-on-one mentoring sessions (by arrangement), externally-organized scientific seminars, and two rounds of a 3-session R Workshop (six sessions total). Below, we describe each of those categories, and present event survey data and student quotes about each.

Alumni Career Panels. We organized 16 alumni career panel events, to which we invited 25 alumni. These sessions were either 60 or 90 minutes, which allowed for audience interaction and questions. The alumni were sent questions in advance (see Appendix C) to encourage sharing personal narratives that would engage students by focusing on the

Table 4. *Average Score for How Engaging and Informative Students Found the Various Types of Programming*

Please rate this event, based on how engaging and/or informative you found it (extremely, very, somewhat, not very, not at all)	**Average score** (5 = best, 1 = worst)	**n** (number of event surveys)
Alumni career panels	4.50	236
Current student panels	4.47	105
Journal clubs	4.69	36
One-on-one mentoring sessions	5.00	10
Externally organized scientific seminars	4.30	154
R Workshop (3-session summer version)	4.31	16
Total (all categories)	**4.46**	**557**

alumni's background and career path. The sessions were not research seminars and no slides were necessary.

We focused on recent alumni (graduating between one and 10 years) to foster the benefits of near-peer mentoring and the ability of the students to connect with the alumni personally (Bradley et al., 2022; Carey et al, 2022). We invited 25 alumni from a wide range of degree programs and career paths: five in PhD programs, one in an MD/PhD program, four in MD programs, one in a DO program, one in a PA program, one in a DDS program, one in an MPH program, two in post-baccalaureate research programs, one in a post-doctoral fellowship, two in medical residencies, three working in industry, one working as a teacher, one working as an EMT, and one working as a medical assistant.

From the 16 alumni panel events, the 236 completed event surveys gave an average score of 4.50, which is between "extremely" and "very" informative and/or engaging (Table 4). Student quotes showed an increased understanding of the difference between various paths, such as this quote about the two types of medical school degrees (DO and MD):

> *Previously, I had heard of DO but never knew what it exactly entailed and how it was different from an MD. This event helped me learn more about this career pathway as well as the PA school track. It was very exciting to hear that PA's can move between specialties (and even work in the operating rooms) – I never knew this prior to today.*

Students obtained invaluable information about the various grad school application processes that help them be more prepared for their own future applications. One student wrote:

> *I found that explaining more about the funding process was helpful in applying for PhD programs because before this event I knew very little about it so I feel comforted by the fact that there is plenty of funding out there that I can apply for.*

Current Student Panels. We organized seven current student panel events led by a total of nine near-peer mentors who were rising seniors at UMass Boston. These students were able to provide invaluable advice about how they obtained their undergraduate research experiences, research funding, teaching and tutoring experiences, and clinical experiences. Again, these panels were informal and casual in tone, rather than being research seminars. Like the alumni panels, we asked the current students to share their own personal experiences, and what advice they have for students earlier in their training path. These presentations were beneficial not only to the student participants, but also to the student presenters, for whom giving these presentations provided a valuable professional development opportunity.

Between the seven current student panel events, the 105 completed event surveys gave an average score of 4.47, which is between "extremely" and "very" informative and/or engaging (Table 4). Student quotes from these event surveys showed that the students learned concrete information about how to find a research position, how to obtain funding, and all of the different kinds of life science research occurring on campus. One student commented that:

> *This event was very informative in terms of giving more details about what occurs in the research field. I learned more about fellowships and how undergraduate research students can apply to as many to help fund their lab research. I also learned that there are many types of research (ie: wet lab, clinical, public health, etc.).*

Journal Clubs. We held four journal club sessions; in each, a rising senior would present a primary research article relating to the field of their undergraduate thesis research. The journal club sessions were highly interactive. Each figure was assigned to a small group of three to four students who would analyze the figure in a breakout room, with a rising senior serving as a coach. When we reconvened to the main room, each small group would present an analysis of the figure they were assigned.

These sessions served as professional development for the student presenters, as well as the participants. Honors College scientists would work with the student presenters on thoughtful paper selection, which is key to student engagement and learning in journal clubs (Howard et al, 2021). Before each session, Honors College scientists would lead a pre-journal club prep meeting for the six rising senior "coaches," to go through the paper in great detail in preparation for their role. We discussed primary research articles on topics including microbiology, disease ecology, population biology, and environmental remediation. A full list of articles we discussed in our journal clubs is included in Appendix B.

From the four journal club events, the 36 completed event

surveys gave an average score of 4.69, which is between "extremely" and "very" engaging and/or informative (Table 4). Students wrote about how they appreciated the interactive format of the event, and how these informal journal clubs reduced the intimidation they previously felt to reading primary literature. For example, one student wrote:

> *I didn't expect myself to say this so soon, but reading and analyzing scientific papers with all of you has become the event I'm looking forward to. I really enjoyed the paper and the discussion that followed it. It is helping me understand better and reduce the fear factor into dealing with another scientific paper.*

One-on-One Mentoring Sessions. One-on-one mentoring sessions were available to students with both the alumni presenters and the scientists on staff in the Honors College. These meetings were arranged individually with the students, and were 60 or 90 minutes in length. Students informed the mentor in advance whether they would like a discussion about career options, a review of resumes or personal statements, or a mock interview.

Ten students chose to do one-on-one mentoring sessions. The 10 event surveys earned an average score of 5.00, indicating that every student found the mentoring sessions to be "extremely informative and/or engaging" (Table 4). Quotes indicated that these meetings helped them to prepare for future application processes in concrete and direct ways. One student wrote that their meeting "really helped me get on track with my application process and we met to check in about MCAT cancellations, contacting professors, and thinking about volunteering. It really helped over the following few weeks and I'm much more prepared to apply." Student comments were in line with the published literature about the impact on STEM students of having one-on-one conversations with mentors (Byars-Winston et al., 2015; Estrada et al., 2018), and with the improvement that Honors College scientists saw over the summer with the students' resumes and personal statements.

Opportunities to Attend Externally Organized Scientific Seminars. Because several organizations were moving their seminars online in Summer 2020, we chose to refer our students to other programming held locally and nationally, rather than to organize a seminar series ourselves. We referred the students to the NIH (https://www.training.nih.gov/home) and to the CURE Program at Dana Farber/Harvard Cancer Center (Michel et al, 2021), because both organizations were designing events specifically for undergraduate students, and were thoughtful in choosing speakers who are representative of the diversity of the population in our state and country (Atkins et al, 2020; Erickson et al., 2022; Stephenson-Hunter et al, 2021). Specifically, we referred the students to seven weekly seminars and a full-day "Education Day" hosted by CURE, and to three events and a one three day-long graduate school fair hosted by the NIH (see Appendix D).

The 154 event surveys completed about these seminars gave an average score of 4.30, which is between "extremely" and "very" informative and/or engaging (Table 4). Student quotes indicated that these seminars were exposing students to entire realms of research that they hadn't previously been exposed to. One student wrote:

> *Thanks to [these] events, I have begun to look at the American healthcare system through different lenses. I have started to think more about equity, how to address and combat disparities, and how the implication of technology can help with this battle in the healthcare system.*

R Workshops (3-session summer version). In Summer 2020, we ran two identical 3-day R workshops (totaling six sessions) designed for life science majors with no coding experience, in order to train students on how to use the programming language "R" to perform statistical analysis and to generate data visualizations from large datasets. A total of 26 students attended, with 12 students attending all three sessions. The full curriculum we developed is available on GitHub at: https://github.com/chfal/R_Workshop. The workshop was designed to consist entirely of hands-on activities, most of which were done individually by each student. At least one time during each session, each TA would take a small group of students into a breakout room to work on generating a table or figure from a particular dataset. Upon returning to the main room, each group would present their work and results to the full class. Like with the journal clubs, rising seniors led the sessions (after pre-meetings and training with Honors College scientists), contributing to their professional development.

The curriculum goals for the first day were for students to learn how to: use R Studio, import and explore datasets, do basic descriptive statistics (e.g. mean, SD, etc.), and make scatterplots. On the second day, students learned how to transform data using the dplyr package (e.g. how to manipulate data using functions including select, filter, group_by, arrange, count, etc.), and how to make box plots. On the third day, students learned how to make models, add lines of best fit onto their scatterplots, and determine whether two variables are significantly correlated.

Between the two identical versions of the 3-session workshop, the 16 completed event surveys gave an average score of 4.31, which is between "extremely" and "very" informative and/or engaging (Table 4). The positive response to this

workshop was particularly striking given that most students had no coding experience. A total of 26 students filled out a workshop interest/registration survey, and when asked "Do you have previous coding experience?", 12 chose "I have no coding experience," 10 chose "I have a little bit of coding experience," and only one student chose "I feel comfortable writing code in at least one language" (Table 5).

Students appreciated how the workshop was designed specifically for students majoring in the life sciences who have never written code. One student wrote in a post-workshop survey:

> *This event was very engaging when it came to learning how to use R Studio. As a student who has minimal experience with coding, [the instructors] were nice enough to make it simple for me to understand. I think that R Studio will be a very useful application for me to know, especially since I am interested in becoming a researcher.*

R Workshops (5-session spring version). Because of the demand for our summer R workshops, we held additional R workshops during Spring Break of 2021. We expanded the curriculum to be two identical 5-day workshops (totaling 10 sessions) for two reasons. First, we wanted more instruction time so that the students had more opportunities to work with large publicly available life science datasets. Second, we wanted to prepare the students for an optional extension to the Spring Break program, namely spending the remaining eight weeks of the spring term working to extend the R workshop into an independent research project of their choice.

The R workshop was specifically designed to engage life science majors by analyzing data from two large publicly available data sets showing the prevalence of a wide range of human diseases around the world over time, namely the GapMinder database (www.gapminder.org/data/) and the Global Burden of Disease Study (IMHE, 2020). The first three days of the curriculum were identical to the first three days of the summer workshop. On the fourth day, two of the student instructors each modeled an example of a question they chose to ask about human health around the globe, and how they used R to analyze data from the GapMinder database to create figures to address a specific question of interest. The fifth day of the workshop was focused on the Global Burden of Disease Study, and how to use the free online tools developed by that group to create data visualizations analyzing the massive amount of data about human disease prevalence that has been collected worldwide over the decades of this project (IMHE, 2020).

For the Spring Break R workshops, 24 students attended, and 20 students completed the full week of the program. In a post-workshop survey completed by 19 students, when asked "Please rate this workshop, based on how much you feel you learned from it," the average score was 4.58 (out of 5.0) which is between "a ton!" and "a good amount." When asked "Please rate this workshop, based on how engaging and interesting you found it," the average score was 4.42 (out of 5.0) which is between "extremely engaging!" and "very engaging."

Table 5. *Prior Coding Experience of Student Participants in R Workshops.*

Do you have previous coding experience?	**Number of students selecting this rating** (Summer 2020)	**Number of students selecting this rating** (Spring 2021)	**Number of students selecting this rating** (**TOTAL**)
"I have no coding experience."	12 (46.2%)	13 (54.2%)	25 (50.0%)
"I have a little bit of coding experience."	10 (38.5%)	10 (41.7%)	20 (40.0%)
"I feel comfortable writing code in at least one language."	1 (3.8%)	0 (0.0%)	1 (2.0%)
No response	3 (11.5%)	1 (4.2%)	4 (8.0%)
n (Total number of post-workshop surveys)	26	24	50

The student quotes made it clear that the students appreciated how the seminar was designed for those without coding experience, and how it was designed to be very engaging and hands-on. For example, a participant wrote in the final post-workshop survey:

> *All of the instructors and leaders made us feel comfortable to not be afraid to ask questions or say we had an error and instead encouraged it; they really wanted us to learn and were excited which made me even more excited to learn. I loved how we tied the coding to data in presentations; I loved the discussions we had, it definitely widened my scope of interests and working with other people was fun!*

The positive response was particularly striking given that we were introducing R to students who had very little coding experience. A total of 24 students filled out an interest/registration survey and when asked "Do you have previous coding experience?", 13 chose "I have no coding experience," 10 chose "I have a little bit of coding experience," and zero students chose "I feel comfortable writing code in at least one language" (Table 5). We noted that the vast majority of our workshop participants (18 out of 20 program completers) self-identified as female. Our workshop clearly created an environment that allowed life science majors with little coding experience to gain quantitative skills in a setting that they found interactive, comfortable, and not intimidating.

Spring Semester Remote Individual Research Projects. Out of the 20 students who completed the spring break R

workshop, two students chose to spend about 5 hours per week for the remaining eight weeks of the spring term doing an optional extension to the workshop. Each student developed a question about a disease or country of their choice, and addressed those questions by using a combination of R, data from GapMinder, and the data and freely available data visualization tools from the Global Burden of Disease Study (IMHE, 2020).

The final product was a research paper containing all standard sections of a scientific paper, at least one figure they generated using the data visualization tools from Global Burden of Disease, and at least one data figure generated by code they had written in R to analyze data from the GapMinder database. Students met incremental deadlines approximately every two weeks, including submission of the research question, the code they wrote, the figures they generated, a draft paper, and the final paper. At each stage of the project, students received personalized feedback (written, and via Zoom meetings) from the workshop instructors.

Two students completed the Spring Remote Research Program, and the titles of the research papers they produced were "Global Burden of Breast Cancer: A Comparison Between High and Low SDI Nations," and "Greenland's Youth Smoking Problem." Sample student work from these research papers can be found in Appendix E. While several other students expressed sincere interest in doing these research projects, they ended up not embarking on the project due to their schedules after spring term classes resumes. In the future, it may work better if we offer these individual projects over our summer term and/or our 3-week winter term, when far fewer students are balancing classes along with employment.

Follow-Up Surveys. In Fall 2022 (two years after our summer programming, and one year after our spring programming), we sent a follow-up survey to the 48 students who completed either the Summer 2020 program, the Spring 2021 program, or both. Out of these 48 students, 19 completed this follow-up survey, answering questions about how this program impacted them in the years since it occurred. The results of this follow-up survey demonstrated these students' interest in future careers in research, and the impact that this programming had on them.

The students' interest in future research opportunities was surveyed using the question "Do you plan on pursuing any type of research opportunities in the future (e.g. undergraduate research, graduate research, employment in a research position, etc.)?" Out of 19 respondents, 14 said "yes," four said "maybe; not sure," and only one student said "no." Indeed, these students have selected post-college opportunities that indicate a strong interest in the life sciences and in research. The 14 alumni who answered the question "If you have already graduated, what are you currently doing (which type of job, which type of grad program, etc.)?" listed 16 current positions (as two were holding multiple positions). Out of those 16 positions, eight are research technicians, three are pursuing PhD programs, two are pursuing dental school programs, and three are health care workers (one EMT, one PCA, and one MA).

The follow-up survey results indicated that our programming had a deep impact on the students' interest in and applications for science/research opportunities in the future. We asked the students: "Do you feel like this program strengthened your applications to subsequent/future experiences (undergraduate research positions, employment, grad school programs, etc.) in any of the following ways?" (Figure 1). Out of 19 respondents, 15 added the program to their resume, nine mentioned the program in interviews or personal statements, seven received feedback during the program to improve their resumes and personal statements, and seven obtained a letter of recommendation about participating in the program. Only one respondent selected the option "none of the above" (Figure 1).

To further measure benefits of the program, we asked "How helpful were these Honors programs/events to you in…" and asked the students to rate seven potential benefits using a 4-point Likert scale (Figure 2). For every one of the seven categories, the vast majority of students (between 15 and 18 students, out of the 19 total respondents) chose ratings of "very helpful" or "helpful." These results demonstrate that the students found the programming helpful in all categories on the follow-up survey: preparing for a variety of future experiences (research, teaching, clinical, and post-college opportunities), learning about research topics and science careers, reading primary literature and analyz-

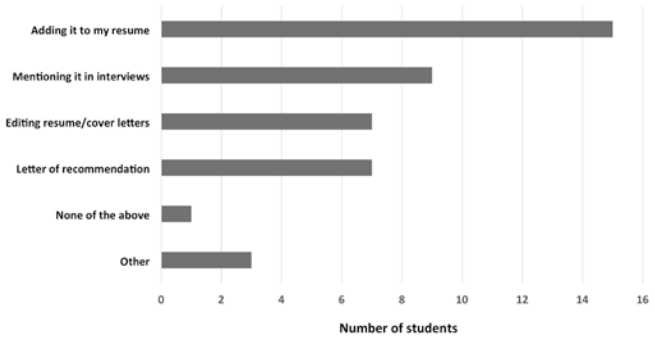

Figure 1. Follow-up survey responses about program impact on students' applications to future research opportunities. Students were administered a follow-up survey in Fall 2022, to measure the impact of the Summer 2020 and Spring 2021 programming. Students were asked how the program strengthened their applications to subsequent/future experiences, and were asked to select all that apply. Out of the 19 respondents, 15 added the program to their resume, nine mentioned the program in interviews or personal statements, seven received feedback during the program to improve their resumes and personal statements, seven obtained a letter of recommendation about participating in the program, one chose "none of the above," and three chose the option "other."

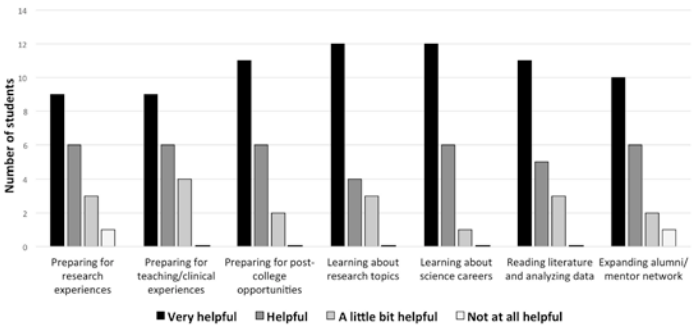

Figure 2. Follow-up survey responses about program benefits and helpfulness. Students were administered a follow-up survey in Fall 2022, to measure the impact of the Summer 2020 and Spring 2021 programming. Students were asked "How helpful were these Honors programs/events to you in…" and students rated seven potential benefits using a 4-point Likert scale ("very helpful" is shown in black, "helpful" in dark gray, "a little bit helpful" in light gray, and "not at all helpful" in white). For each of the seven categories, the vast majority of students (between 15 and 18 students, out of the 19 total respondents) chose ratings of "very helpful" or "helpful."

ing data, and expanding their alumni and mentor networks (Figure 2).

When asked the open-ended question "Please feel free to provide any comments here about these Honors events and programs, and/or how they impacted you," eight students chose to share comments about the impact of our programs. Two of those students commented on the value of the skills they built, and six of those students discussed the connections they made to alumni and current students. One student wrote:

> *Meeting remotely with alumni UMB students and learning about their career paths was really helpful in understanding the diversity of research pathways. Attending the graduate school panels also helped me get the first impressions on what types of candidates the schools are looking for. This gave me awareness on how to better prepare myself and apply to research-related opportunities outside of campus.*

Another student wrote: "From medical professionals to professional researchers ranging from newly started to seasoned veterans, [they] gave me a holistic approach to planning out a post-graduation roadmap."

DISCUSSION

Main Goals. In this study, we created two rounds of flexible and accessible programming for undergraduates to build research skills in the life sciences. These programs were designed for a different purpose than undergraduate internship programs, namely to serve as a launch-pad for gaining future undergraduate research experiences. It accomplished this by providing the students with information about careers, mentoring and networking opportunities, and skill-building such as statistical analysis, data visualization, and reading primary literature. It also directly contributed to students' abilities to obtain future research experiences by providing a program that can be added to a student's resume, and opportunities to get letters of recommendation and feedback on their resumes and personal statements.

We plan to continue this programming well beyond the pandemic during which it was designed. Building research skills and mentoring opportunities is key to addressing issues of the "leaky pipeline" in STEM, which particularly impacts student populations such as those at our highly diverse public university (Byars-Winston et al., 2015; Estrada et al., 2018). Obtaining a first research experience can be challenging, because summer undergraduate internship programs are often very selective national processes that receive hundreds of applications, and can favor students with prior research already (Barber et al., 2021; Chase et al., 2020; Corson et al., 2021; Johnson and Knox, 2022). These selective programs are often also looking for students who have multiple letters of recommendation, and professionally written resumes and personal statements. Highly selective application processes can present hurdles to students who don't have connections in their networks already (Jelks and Crain, 2020; Stephenson-Hunter et al, 2021). Programs such as ours can thereby increase access for students to obtain future research experiences.

Benefitting Students Beyond the Pandemic. We designed this program to offer our students opportunities for mentoring and networking, skill-building, and career development. Opportunities for mentoring and networking came from our alumni panels and our current student panels. These were designed to be personal and informal, rather than for example seminars about the presenter's research. The students saw themselves in these alumni and strongly connected to elements of their shared experiences, like attending the same university, but often also from similar communities and backgrounds. The power of bringing in these alumni is demonstrated in the students' final self-reflections (Table 3), which included numerous passages with the theme of meeting those with shared experiences:

> *As a first-generation college student, connections are hard to come by. What truly aided these growing fears and imposter syndrome were simply hearing the stories of others. The struggles and hardships that students faced and how they were still able to receive an acceptance towards a medical school. This was my specific reason for joining this career program. I knew that I would be able to hear the life of those before me and potentially rekindle why I am studying for endless hours and why I am willing to dedicate another decade towards education.*

The power of having mentors with shared experiences has been shown to be particularly impactful to students in populations historically under-represented in STEM (Atkins et al, 2020; Erickson et al., 2022; Stephenson-Hunter et al, 2021).

Opportunities for skill-building included our journal clubs and R Workshops. Building these skills before the students' first research experience is very helpful to both the students and their future PIs. There is so much to learn when first joining a research group, both the generalizable research skills like reading literature and analyzing data, but also the techniques specific to generating data in the student's specific research group. Programs like this one can help students gain some of these skills before a first research experience begins, which may help students focus on developing analytical skills in advance, when they aren't also juggling a focus on manual skills and data collection (Fung et al., 2021).

This program directly contributes to the progression of these students' careers in the life sciences, because the program makes them more marketable for future research positions. Having experience in their field also makes students more confident in pursuing future opportunities (Adedokun et al., 2013; Byars-Winston et al., 2015; Estrada et al., 2018; Tate et al, 2015). Our students often don't have connections in their networks with scientists who can guide them in how to find a research opportunity or craft their resume (Jelks and Crain, 2020; Stephenson-Hunter et al, 2021). This program provides them with a certificate of completion for their resume, a recommendation letter from a scientist, and the opportunity to have one-on-one guidance around their career interests and resumes. Our program thereby prepares students for obtaining future research opportunities, which is a need that exists both during and beyond a pandemic.

Key Features of our Programming. Below we share insights gained from implementing this program, including key features that contributed to its effectiveness. We hope these insights will be helpful to other institutions in crafting similarly flexible and accessible programs that prepare undergraduate students for their first research experiences.

Our program offered clear and concrete incentives to the student participants, above and beyond the skill building and mentoring opportunities, namely: a certificate of completion to put on their resume, and opportunities to obtain a recommendation letter and input on their resumes and personal statements. In this way, participation in this program can directly lead to increasing the students' marketability for applying to future undergraduate research programs.

We designed our program to be flexible in many ways, which was crucial for our student population because the vast majority our students balance their coursework with employment and commuting. First, students could choose any 12 events in the summer from a selection of the 33 events we organized. Second, students did not have to commit to completing the program at any point; rather, they were simply deemed as completing if they reached the 12-event minimum by the end of summer. Third, students could choose to participate in summer, over spring break, or both. These options were during breaks in coursework, when students' schedules are more flexible. Finally, we offered events on all five weekdays, and at various times in morning, afternoon, and evening to accommodate a variety of student work schedules.

Contributing to the flexibility is the fact that our program was fully virtual. This is particularly impactful at our urban R2 public university, where most students live off-campus and work a substantial number of hours each week. The virtual modality also allowed us to invite speakers from around the country. The literature about virtual life science research programs has highlighted these benefits of virtual programming, as well as benefits to students in rural and/or international locations, students with reduced mobility, and students with family/childcare responsibilities (Chin, 2020; Corson et al., 2021; Erickson et al., 2022; Johnson and Knox, 2022; Michel et al., 2021; Oliver et al., 2021; Samad et al., 2021).

Another key program aspect was variety. Students were able to choose from six different types of events (alumni panels, current student panels, journal clubs, R workshops, external scientific seminars, and one-on-one mentoring meetings). A great deal of variety was present in the wide range of careers and degrees represented by our alumni. We felt this was important because our students often don't know what careers interest them most, and how many science-related career options exist.

The alumni panels were also designed to emphasize the personal and human elements of our alumni's stories. The final self-reflections our students wrote made it abundantly clear that the personal element of these talks was deeply impactful to them (Table 3). The impact of hearing personal stories about career paths has been highlighted in the literature, both in papers about virtual life science research programs (Oliver et al, 2021), and in research surrounding the importance of students having access to mentors who share features of their various backgrounds (Atkins et al, 2020; Erickson et al., 2022; Stephenson-Hunter et al, 2021).

Utilizing alumni networks allowed us to greatly expand our capacity for mentoring our students. At the time of this programming, the Honors College had 240 life science majors, but only employed two scientists. Being able to bring in 25 alumni to engage with this program greatly increased the range of careers we could introduce the students to, and expanded our ability to mentor these students. We found this capacity-building feature to be unique among the Summer 2020 programming described in the literature, with just one paper mentioning holding one alumni career panel event (Carey et al, 2022).

We also expanded our mentoring capacity by employing

current students (rising seniors) to serve as near-peer mentors to our students. The students we employed gave current student panels, led journal clubs, and assisted in designing and teaching the R workshops. This sort of near-peer mentoring clearly benefits the mentees (Bradley et al., 2022; Carey et al, 2022), and we saw clear benefits to the rising seniors as well. The four students we employed are now all in graduate school (three in PhD programs and one in an MD program), and all four requested letters of recommendation from the Honors scientists who organized the program when applying to their graduate schools and fellowships. Their roles in this program not only impacted their resumes, but more importantly their own future career interests. These student employees wrote self-reflections also, and one wrote:

> *This also helped me to realize I have a passion for teaching and helping others. I enjoyed helping students find research opportunities, coaching students individually in breakout rooms during the R workshop, and helping students break down difficult scientific papers for the first time in journal clubs. Although I do not know for certain what I will be doing after graduate school, the option of becoming a professor is now something I'm considering that I hadn't previously. Helping students feel less overwhelmed and understand difficult concepts brings me a lot of joy.*

The professional development opportunities our seniors received by leading program events were unique in the literature on virtual life science research programs, which occasionally mentioned graduate student TAs, but mainly focused on sessions led by post-doctoral fellows and faculty members.

Another key element is that our program was accessible to students in all years of college and with all levels of experience. We utilized a sign-up (not an application process) and were able to accommodate all 87 interested students. Many undergraduate internship programs run national application processes that attract hundreds of applications for a small number of slots (Barber et al., 2021; Chase et al., 2020; Corson et al., 2021; Johnson and Knox, 2022). For our program, students do not need a resume, a personal statement, or a letter of recommendation to participate. Thus, our program is accessible to students with no prior research, and no prior connections to scientists.

A major goal in our design was to create events that were not intimidating, and hopefully casual and even fun. Our program was designed specifically for students with no prior wet-lab experience or quantitative skills. We were particularly struck by the lack of intimidation that students felt around building quantitative skills in the R workshops. The participating students came in with no or little coding experience and found the sessions engaging, which we attribute in part to these sessions being focused on practical knowledge that directly related to life sciences, by utilizing datasets relating to human health around the globe. We were surprised but thrilled to find that 18 out of the 20 completers for our Spring Break R workshop self-identified as female. We feel that this low-stakes, free and short format allowed life science majors to try out their hand at coding and data visualization, in a way that was neither a graded course, nor an expensive coding bootcamp. The R workshops and the subsequent optional spring-semester research papers were non-intimidating ways to test the waters on gaining quantitative skills that would allow students (who might initially be hesitant) to gauge interest in further coding or statistics training. This serves a different purpose than other virtual coding workshops held for life science students, which are often geared towards graduate students or to undergraduates working in computational research groups (Carey et al, 2022; De la Fuente et al, 2021; Jensen-Ryan et al, 2021; Parrington and Giardino, 2021).

All of our programming was designed to be fully interactive. The R workshops and journal clubs were centered around hands-on activities. The alumni panels and current student panels were informal conversations, not research seminars. The one-on-one mentoring sessions were entirely customized to each student's needs. This type of interactive and skills-based learning has been shown to be key in retaining students in the STEM "leaky pipeline", and in particular retaining students in groups historically under-represented in STEM (Chang et al., 2014; Graham et al, 2013; Jelks and Crain, 2020; Theobald et al., 2020).

Key logistical aspects of the program included it being free of cost to the students, and low cost to the institution. Being free of cost to students is key to our student population in particular, as a majority of our students come from low-income backgrounds and must balance employment with school (OIRAP, 2020; UMass PMS, 2021). Being low-cost to the institution is also an important factor, especially to a large public university. The two scientists employed by the Honors College were able to implement this programming with no expenses occurred other than paying the four student TAs mentioned previously. This is in contrast to undergraduate summer internship programs, which often require PIs to obtain sizeable grants from selective national grant application processes (NSF, 2022).

Despite being low-cost to the institution, the program was able to accommodate a sizable capacity in terms of number of student participants, namely 63 in summer and 24 over spring break (87 in total). This is much larger than the capacities of undergraduate internship programs, which are constrained by needs for lab space, funding for equipment and reagents, and research mentors. Our two Honors College scientists (who were balancing this program with their full-

time roles as faculty members and administrators) were able to accommodate all 87 students who chose to participate in our programming.

The over-arching goals of our program are to prepare our students to apply for future research positions by building their research skills, their resumes and personal statements, and their connections to alumni mentors. We achieved these goals by creating a program that is free of cost, flexible, virtual, and accessible. We created a program with a personal, interactive, and non-intimidating tone that built confidence and knowledge of career options. We provided students with opportunities for skill-building, networking, mentoring, and career advancement in ways that directly address issues of the "leaky pipeline" in STEM – issues that have particular impact on the student populations at large public universities such as ours, who are often first-generation college students and/or are students from historically marginalized communities (Byars-Winston et al., 2015; Chang et al., 2014; Estrada et al., 2018; Graham et al, 2013; Jelks and Crain, 2020). We plan to continue this virtual programming well beyond the pandemic, during summers, spring breaks, and winter terms. We encourage other institutions to add this sort of flexible and accessible programming to the cadre of very impactful (but highly selective, and lower-capacity) undergraduate research internship programs that have now returned to in-person operations in universities around the country.

ASSOCIATED CONTENT

Supplemental material mentioned in this manuscript can be found uploaded to the same webpage as this the manuscript.

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Author Contributions

The manuscript was written through contributions of all authors. MER and AC designed and implemented the programming, administered and analyzed the surveys, and took lead roles in preparing the manuscript. CF and FS gave comments on the manuscript, and designed and taught the curriculum for the R course, with input, assistance, and oversight from MER and AC. All authors edited the drafts and have given approval to the final version of the manuscript. The authors have no conflict of interest to disclose.

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ABBREVIATION

REU: Research Experiences for Undergraduates

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