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Four Years of 'Students as Researchers Initiative': A Summer Internship Engaging High School Students in STEM Research in Lebanon

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ABSTRACT: This practice-based article describes a program that aims to fill the gap in STEM education by introducing high school students to the research culture while offering them the chance to engage in scientific research early in their careers. The Students as Researchers Initiative (SRI) developed by AMALOUNA, an American University of Beirut affiliated educational organization, is an 8-week program which matches students to research mentors and allows them to gain a hands-on laboratory experience, generate data, and share findings with a scientific and laypeople audience. Since its launch in 2016, the program has grown with a total of 64 students up till 2019 and around 50% of its alumni pursuing a career related to STEM. The program received positive feedback from both students and their mentors. It appears to have solidified students' interests in STEM and their consideration for STEM-related careers, introduced them to new skills and acted driver for their self-discovery and future career choices.

INTRODUCTION

Despite being ranked third in the MENA region for the number of publications in biomedical and health research (El Achi et al., 2020), research and innovation in Lebanon still lag behind. Most universities in the Arab region emphasize teaching over research, and Arab researchers report that their environment often does not support doing science (Pakinam, 2019). In 2019, the number of scientific publications in Lebanon was 482.8 per million inhabitants, compared to 1,226.9 in high income economies (1,648.3 in North America and 1,457.4 in the European Union) (UNESCO, 2021). Additionally, between 2015 and 2019, Lebanon saw a 7.3% decrease in the number of patents, despite the Arab region seeing a 63% increase (UNESCO, 2021). The 2021 UNESCO Science report also found that cross-cutting strategic technologies in Lebanon are not specialized and have low impact. These numbers highlight the need for programs to improve the country's research and innovation.

Importantly, the need for improved Science, Technology, Engineering and Mathematics (STEM) education is also pronounced in Lebanon. In 2019, according to the Trends in International Mathematics and Science Study (TIMMS), Lebanon's average Grade 8 mathematics and science achievement scores was significantly lower than the center point of the TIMSS scale (Mullis et al., 2020). Additionally, in the same year, only 26.79% of students achieved at least a minimum proficiency level in mathematics by the end of lower secondary education (UNESCO Institute for Statistics (UIS), n.d.). STEM education in Arab countries need to be complemented by research experience in laboratories or technology companies to help students acquire knowledge

and develop skills about science and research (BouJaoude, 2020). High school students with interest in STEM often lack practical research and laboratory experience (Holmes et al., 2018). While they learn about various topics related to the STEM field inside the classroom, they may struggle to apply their knowledge and skills in real-world settings (Wilson Gilmore, 2013). In addition, didactic learning that dominates in classes causes a gap between theoretical and applied knowledge (Gillies and Boyle, 2010; Holmes et al., 2018). This gap reveals the need for enrichment programs that adopt experiential learning, to engage learners in practical training and allow them to reflect on their actions (Mughal and Zafar, 2011). Gaining practical experience through participating in extracurricular activities provided by academic institutions was shown to enhance students' abilities to retain knowledge and improve their skills (Landrum and Nelsen, 2002). The recognized benefits of hands-on experiences have led to the development and support of research experiences for undergraduates (REUs) by organizations such as the National Science Foundation and the National Institute of Health. These programs allow institutions to recruit top applicants who are interested in growing their research experience. Lebanon lacks such programs that either develop research skills or highlight the important role of research on impacting developing countries.

Herein, we describe the Students as Researchers Initiative (SRI) as a unique initiative that aims to fill the gap in STEM education by introducing the research culture to high school students while offering them the chance to engage in scientific research early in their careers. This practice-based article describes four years of the SRI program with 64 students, discussing its different components, its evaluation, and its impact on participants. It is worth noting that the program was not implemented in a research project framework. Hence, the data presented hereafter was meant to inform the program director and coordinators about the program strengths and weakness and guide its improvement to achieve its intended objectives.

SRI PROGRAM DESCRIPTION

The SRI program was launched in 2016 by AMALOUNA (أملنا| Beirut | Facebook, n.d.), an American University of Beirut (AUB) affiliated educational organization that aims to highlight the importance of research, and make research opportunities available for high school students from different backgrounds by providing them with a chance to conduct research projects at the AUB research facilities. It is an 8-week program, and runs on a yearly basis during the summer session at the AUB Faculty of Medicine. The program is free of charge and offers both theoretical and practical trainings to interested students who come from different socioeconomic and academic backgrounds.

SRI offers students an exceptional opportunity to be engaged as a team in small research projects, gain insight into what scientists do in the real world and become familiarized with scientific research as a career option. The SRI curriculum teaches students to apply the scientific method in a research project to develop a research question, search the literature, perform experimental techniques, generate data, analyze results, and communicate their findings to a scientific audience and the family of the students at the final SRI conference.

Program Objectives

1. Introduce high school students to scientific research as a career option
2. Improve students' skills around research design, hypothesis formation, experimental techniques, data collection and data analysis.
3. Improve students' oral, visual, and written communication skills

Recruitment Process. Students in Grades 10 or 11, enrolled in a public or private school, are recruited from Beirut and nearby cities to join the Faculty of Medicine at AUB and work on diverse research projects during their summer break. In the Spring, members of the SRI team present the program at different schools to introduce the program to students. Interested students fill an application form and write a motivational letter to describe their interest in scientific research. Participants are then selected according to their interest in research and their proficiency in English, which is taught in the curriculum at public and private schools. Admission decisions are made irrespective of their school grades or their socio-economical background while ensuring a balance in the number of students from public and private schools. The selected applicants are then invited to join the SRI program which consists of six essential components that support the program's main objectives.

Orientation (One Week). The program begins with an orientation session during which students are introduced to the general objectives of the program and taught about the scientific method. During this session, they also receive training on finding scholarly articles, organizing information, and performing a literature review. These themes were selected based on programs with the aim to empower students to be involved in research such as the Virginia Tech Advanced Research Skills Certificate Program (Miller et al., 2022). Students also follow training on lab safety guidelines necessary for their involvement in research.

Team Allocation (One Day). Following orientation and initial trainings, groups of two to three students are random-

ly assigned to a research project. Several faculty members participate in the implementation of the program by hosting the students in their labs and assigning them mentors, usually graduate students, postdoctoral fellows, or research assistants. Mentors supervise students in conducting experiments and serve as their main point of contact for questions about the project. The model of students-mentors teams was chosen in line with the situated learning theory, with the goal of creating a community of practice (COP) (Lave and Wenger, 1991; Wenger, 2011). The community of practice framework establishes a social learning structure that brings together individuals with shared interests to foster collaboration, share knowledge and develop expertise through active participation and shared practices and resources (Lave and Wenger, 1991; Wenger, 2011). Programs following the COP framework resulted in promising outcomes such as retention of students in STEM in diverse populations (McCreedy and Rudy, n.d.; Winkleby et al., 2009). As such, the SRI program was developed to include the three characteristics of a COP: a shared domain, a co-learning community, and a practice. First, in our case, the shared domain is STEM research. Students and mentors express their interest in the domain through their commitment to the program. Second, the community is formed within each research team (between students working together and between students and their mentors) as well as across different research teams. The SRI community provides an opportunity for students to learn from each other by working together and sharing their research with other teams, and for mentors to share their approaches to teaching and directing their teams. Third, in the SRI program, the practice is research or the approach to answering a scientific question, designing experiments, and sharing results. Students enrolled over four years worked in teams of two to three per project. A list of the 29 research projects is available in Supplementary Table 1 (Appendix A).

Literature Review (One Week). Students first conduct a literature review on their topic. This stage serves as a self-directed learning experience for students to gain a background knowledge of their project. Additionally, reading the primary scientific literature is an important scientific literacy skill. A study investigating the scientific literacy of the Lebanese curriculum found that it lacks emphasis on science as a way of knowing (Boujaoude, 2002). This aspect of scientific literacy refers to the understanding of the scientific process in evaluating and creating new knowledge without bias. By teaching students about the scientific method and guiding them through a literature review, the SRI program aimed to address this gap in their science curriculum.

Experimentation (Four Weeks) and Data Analysis (One Week). The cornerstone of the SRI program is the participation of students in laboratory research. This practical experience introduces them to laboratory equipment, experimental techniques, data generation, and most importantly the day-to-day life of a researcher. The skills covered were different based on each team's project but included keeping a lab notebook/record, formulating solutions of different concentrations, pipetting liquids, cell culture, PCR, and gel electrophoresis. Participants were also mentored on how to collect and analyze data from their experiments. In addition to equipping students with experimental and analytical skills, the rationale behind the laboratory research part of the program was to produce critical thinkers who can design experiments to investigate scientific hypotheses.

Conference Presentation (One Day). At the end of each cycle, the students present their findings in a professional manner by writing a report and orally presenting at the SRI conference, following guidance from and practice with their mentors. Students present to both a scientific audience consisting of their mentors, supervisors and other AUB faculty and staff, and a laypeople audience consisting of participants' families and friends. This final stage of the program is instrumental in developing participants written (report), visual (slides) and oral (presentation) communication. Aside from promoting research communication skills, it provides students with a final opportunity to learn about their peers' work and demonstrate and make meaning of their experience and learning.

At the completion of the program, students receive completion certificates and Standard Admission Test (SAT) preparation books to prepare for the SAT exam that is needed for college applications.

PROGRAM EVALUATION

At the end of each cycle, students were asked to fill an anonymous form regarding their experience with the SRI with the aim of evaluating the program for improvement. The form included nine questions using a 5-item Likert scale with questions around their attitudes towards the different parts of the program and their interest in research. The form also included open ended questions on the strengths of the SRI program and what students have learnt from this experience. Similarly, research mentors were asked to fill an evaluation form with five questions using the same 5-item Likert scale. In addition, in January 2022, all participants were contacted by email or phone for follow up information. During the follow up, students were asked about their career after secondary school (i.e., university, technical school, work) and their involvement in research after the end of the program.

Table 1. *Description of the cohorts of participants and data collected over the four SRI cycles.*

CYCLE			2016	2017	2018	2019
Participants		N	6	16	20	22
Research projects		N	3	8	10	8
Sex	Male	N (%)	2 (33.33)	5 (31.25)	4 (20.00)	10 (45.45)
	Female	N (%)	4 (66.67)	11 (68.75)	16 (80.00)	12 (54.54)
School	Private	N (%)	3 (50.00)	11 (68.75)	15 (75.00)	7 (31.82)
	Public	N (%)	3 (50.00)	5 (31.25)	5 (25.00)	15 (68.18)
School City	Beirut	N (%)	6 (100.00)	11 (68.75)	7 (35)	16 (72.73)
	Saida	N (%)	0	5 (31.25)	11 (55)	6 (27.27)
	Fanar	N (%)	0	0	2 (10)	0
	Aley	N (%)	0	0	0	0
Evaluations at cycle end		N (%)	4 (66.67)	13 (81.25)	14 (70.00)	12 (54.54)
Follow up in January 2022		N (%)	4 (66.67)	12 (75.00)	15 (75.00)	13 (59.09)

PROGRAM OUTCOMES

Sixty-four students (33.3% male, 66.7% female) have been enrolled in the SRI program over four years between 2016 and 2019, and all students completed the program. The SRI program included equal representation from both private and public schools (Table 1). This is particularly important as private and public schools in Lebanon differ significantly in the quality of education and the opportunities available for students (Bahou, 2015). Indeed, as public schools in Lebanon are free (or have very low tuition fees), those attending them usually, though not always, come from low-income families, those who belong to the working class. The parents of some, but not all, of these students have never completed formal education. On the other hand, students coming from private school vary in terms of socioeconomic status. Whereas some come from middle class families, others are well off. Additionally, students attending public school generally present with a stronger language barrier and more limited guidance and experience.

Student Feedback. Forty-three (of the 64 participants) filled the evaluation form at the end of each of the four SRI cycles resulting in a 67.18% response rate. The program was consistently highly rated with 79.6% of the respondents answering that they would recommend the SRI to other students, and around 60% provided an excellent overall evaluation (Figure 1). The majority of respondents (84%) agreed or strongly agreed that the SRI stimulated their interest in research. Additionally, 58% of participants considered research as a career option. Students' evaluations by year and their comparison across years are represented in Supplementary Figures 1 and 2 (Appendix B).

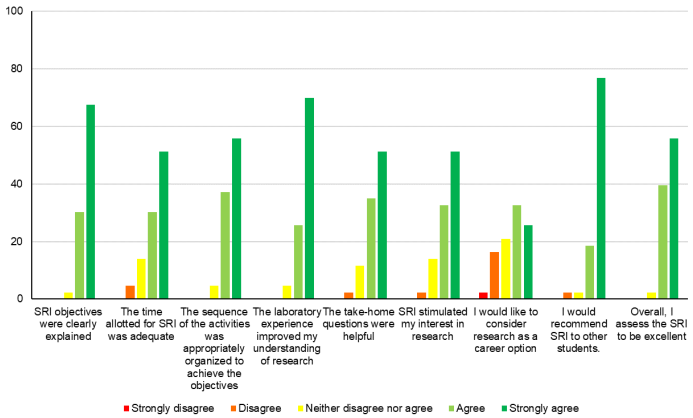

Figure 1. Students' evaluation of the SRI program (%). N= 43.

Students' responses indicate that they gained different skills through the program (Appendix A, Supplementary Table 2). One student refers to the practical experience: "*I got hands-on experience with equipment I wouldn't have otherwise the opportunity to work with*" (2017). Another discusses the experimental, analytical and communication skills gained "*SRI is extremely educational. I am now aware how to interpret results, carry on experiments, and write a report in the proper way*" (2019).

Students' free text responses also reveal that the program was an eye opener or driver for their self-discovery and future career:

> *The SRI is one of the best experiences I have ever been through because it is a unique program that introduces students to the research field that is mainly unknown in our country and in the world. […] the SRI introduces students to the medicine field and it makes them realize if it is applicable for them or if they want to pursue another career. (2017)*

> *SRI was an eye-opening, one of a kind experience for me as a high school student […] I found a world that combines biology and chemistry and physics. I could very much see myself choosing research as a career path in the future. (2019)*

Additionally, we feel that students gained an understanding of the culture of research through the program. For example, one student shares that the SRI "*introduces students to research career and obstacles that researcher may face. In addition, SRI gives students an opportunity to work as researchers and helps them understand the true meaning of research by simple words*"(2017). Other students discuss the impact of research: "*I also learned the importance of research and discoveries that mold the future of humanity*" (2019), and "*In the end, science is always developing especially in terms of human health and development, so being*

a part of the culture of the medical industry really is a huge privilege" (2017).

CHALLENGES

Despite that the program was generally very well received by the students and had an overall positive impact on them, it was not devoid of challenges inherent to the region and to students' prior STEM education and research literacy.

One of the students found it challenging to cope with the huge amount of information he/she was receiving and the little time he/she had to process this information.

> *I personally found it hard to keep up with the bulk of information I was being exposed to at every session. In addition, there were lots of procedures that, despite having read about prior to the session, were highly complicated and only brushed upon during the session. It would have been much easier had there been a time allotted specifically for the explanation of those procedures in depth in order to keep up with what was happening in real time. (2019)*

Moreover, students' suggestions revealed another challenge related to students' English language proficiency, whereby language presented a barrier for some students which hindered them from effectively contributing to the teamwork. For example, "*I was hoping that my partner knew enough English so work as a team can be fair*" (2018).

It also appeared that commuting to the American University of Beirut was among the difficulties the participating students faced. This did not only impact the learning experience of the students who missed some of the research activities and group meetings but also that of their partners in the team.

> *The only miniscule weakness of the SRI is the issue of transportation from Saida, an obstacle we thankfully avoided. This can easily be solved by group communications and compromise. (2017)*
>
> *Please select students that are based nearer to Beirut, because I had difficulty in working with my partner because she wasn't always able to attend our meetings with our mentor. (2017)*

Mentor Feedback. Seventeen of the twenty-nine research mentors filled the SRI evaluation survey totaling a 58.62% response rate. The majority gave a strong overall evaluation of the SRI program (Figure 2). While 71% of the mentors strongly agreed that the SRI objectives were well organized, 65% agreed that the time allocated for the SRI was not adequate because of the program's relatively short duration.

Long-Term Outcomes. Forty-four participants responded by email or phone to the follow up questions when contacted in January 2022, resulting in a 66.75% response rate. All but two, both of whom were from public schools, went to university. Many students (mostly from private schools) were accepted at AUB or other private universities in Lebanon (Table 2). Few traveled abroad, and most of the students who went to the public Lebanese University (LU) were from public schools. The majority of students chose to pursue STEM-related majors: biology (5), biochemistry (3), medicine (3), medical lab (2), nutrition (2), pharmacy (2), nursing (1), chemistry (1), mathematics (1), computer science (2), dentistry (1), and microbiology/immunology (1), engineering (6), architecture (2), graphic design (2), business (2), economics (2), psychology (2), international management (1), and journalism (1). In particular, half (N=21) of the students majored in biomedical sciences. When asked about whether the SRI played any role in the choice of their major, around 50% of the respondents who are currently majoring in STEM fields believed so. Students reported:

"*SRI set me on the track to biology and specifically research. After my experience, I knew this is what interests me.*" (2016, Major: Biology)

"*The SRI played a significant role in sparking my scientific curiosity and introducing me to the field of research.*" (2017, Major: Nursing)

"*The hands-on experience with SRI made me realize where my calling lies, and it is the defining factor that pushed me to choose a career as a scientist.*" (2019, Major: Biology)

"*SRI opened up my eyes to the exciting world of research, and I have not shut up about it since then.*" (2019, major?)

About a third (28.57%) of SRI alumni reported receiving scholarships, and the same number reported participating in research projects at their university. While this number is relatively low, in Lebanon, it is rare for university students to take part in research projects due to lack of opportunities or funds. In general, students reported that the SRI has improved their portfolio and given them a competitive advantage in scholarship applications.

> *It is my pleasure to inform you that I was accepted in the MasterCard Foundation scholarship at AUB, [SRI] was a great experience in my life that motivated me and helped me pursue my higher education at AUB, it also helped me to develop as a person, realize my future career, and know the value of research and its great outcome on patients. So thank you. (2017)*
>
> *I believe SRI definitely gave me a boost in terms of being involved in a project and initiative part of*

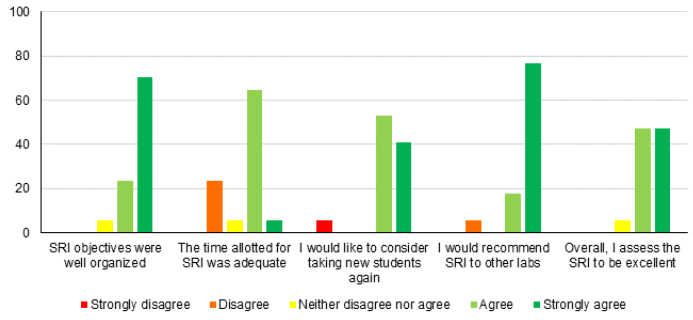

Figure 2. Mentors' evaluation of the SRI program (%). N=17.

AUB and being familiar with AUB and its facilities. (2018)

As one of the few science-related activities I got the chance to participate in as a public high school student, and as the first activity listed on my scholarship application, it proved my interest and passion for the fields I was applying for. (2019)

I received offers in two consecutive years for a vocational research experience scheme program at my university [...] I believe my SRI experience gave me a competitive advantage over other applicants to the scheme. (2017)

Students also reported that they were able to use the skills gained from the SRI in their future involvements, such as for their capstone university project or research work.

Aside the lab work we had to accomplish within my undergraduate years, I had to carry out a complete research on a certain drug efficiency and cell migration in adenocarcinoma, during which I easily integrated some of my previous skills I gained from the SRI, as my graduation project. (2017)

I am currently volunteering as a research assistant in a lab at LAU [...] The opportunity I had with SRI to learn lab techniques as a high school student gave me a competitive edge that allowed me to be picked over other eager applicants to enter directly into wet-lab work, whereas the standard procedure would've included several weeks of basic training. (2019)

The SRI Compared to Other Programs. A wide variety of research institutions in the United States, such as Harvard, Stanford, Emory, and Vanderbilt among others, offer high school students the chance to engage in research in different scientific disciplines. Some of these institutions provide students with a fully funded internship with or without a stipend, while others require enrollment fees (Eeds et al., 2014; Rohrbaugh and Corces, 2011). In Lebanon, there is only one similar research experience program; however, it is exclusive to undergraduate students at AUB (Dagher et al., 2016). However, our program is the first of its kind to target high school students and provide them early on with an opportunity to be actively engaged in biomedical research.

Table 2. *Follow up data in January 2022 of the SRI students who responded and entered university.*

		All N=42	Private school N=27	Public school N=15
University	American University of Beirut	12 (28.57)	10 (37.04)	2 (13.33)
	Private Lebanon	16 (38.09)	10 (37.04)	6 (40.00)
	Public Lebanon	8 (19.05)	3 (11.11)	5 (33.33)
	Outside Lebanon	5 (11.91)	3 (11.11)	2 (13.33)
	Not specified	1 (2.38)	1 (3.7)	0
Major	Biomedical sciences	21 (50.00)	16 (59.26)	5 (33.33)
	Non-biomedical sciences	21 (50.00)	11 (40.74)	10 (66.67)
On scholarship	Yes	12 (28.57)	8 (29.63)	4 (26.67)
	No	30 (71.43)	19 (70.37)	11 (73.33)
Doing research	Yes	12 (28.57)	9 (33.33)	3 (20.00)
	No	30 (71.43)	18 (66.67)	12 (80.00)

Summer programs offering hands-on research experience provide opportunities for high school students to develop their practical and communication skills. Specifically, laboratory experiences promote the application of gained knowledge, practice in problem solving, and development of both general and technical skills (Roberts et al., 2018). For example, students who completed a summer research program at Rochester University developed sophisticated laboratory skills in microbiology and molecular genetics as demonstrated by short-term follow-up (Knox et al., 2003). However, the role of such programs extends beyond practical skills to influence personal growth and career choice. In one similar program, students reported that participating in the Rochester summer research program had a strong influence on their continued interest in science, and many have pursued advanced degrees in science and medicine (Markowitz, 2004). Several studies have shown that informal science education programs help generate and maintain interest in STEM studies and careers (Harrison et al., 2011; Hunter et al., 2007; Knox et al., 2003; Pender et al., 2010; Rohrbaugh and Corces, 2011) and that students preferred active learning and hands-on activities (Piburn and Baker, 1993), and those taught by didactic lectures and handbooks were less likely to pursue STEM degrees (Maltese and Tai, 2011).

Almost all (97%) of SRI alumni entered university and the majority chose STEM-oriented majors. In addition to selecting STEM-related majors, around one third of SRI alumni have continued to be engaged in scientific research. This is consistent with other similar programs. For example, in the case the Emory Research Internship and Science Education (RISE) program, 61% of participants went on to enroll in science-related majors and 20.5% continued their involvement in scientific research after completing the program (Rohrbaugh and Corces, 2011). While it is difficult to assert that these outcomes are related to students' participation in the SRI, we believe that students' exposure to the laboratory environment in different research areas enriched their experience and introduced them to scientific research as a profession.

A recent paper investigated how informal science education can lead to persistence in STEM (Habig et al., 2020). Their analysis found that four program designs principles (Practitioners of Science, Social Networks, Shared Science Identity and Discovering Possible Selves) contributed to persistence in STEM. The SRI program includes all four principles. It provides students with an opportunity to be practitioners of science through investigating a research question with laboratory experiments and analyses. It fosters social networks between high school students interested in STEM and research, mentors, laboratory staff and university educators. In that way, SRI allows youth to view themselves as "researchers" or "scientists" and make educational or professional decisions based on this shared science identity. Finally, the SRI provides students with the opportunity to explore their interests by introducing them to new career options.

From our 4-year experience, we realized that the challenges faced by implementing a program like SRI in the Middle East or the Arab region are different from those faced by similar programs in the United States or Europe. Particularly, the existence of a language barrier might hinder the learning experience of some of the students and that of their peers. Additionally, the absence of a reliable transportation web renders commuting to the research institution an obstacle for students residing away from the institution.

CONCLUSIONS

The SRI is an innovative and successful program providing high school students in Lebanon the chance to learn about and be involved in scientific research and be introduced to careers in STEM and biomedical research. The program facilitated awareness of research culture and allowed students to gain a hands-on laboratory experience, generate data, and share findings with a scientific and laypeople audience. Particularly, towards the end of the program, students gain scientific literacy within an authentic research environment.

Lessons Learned. Implementation of such a program in the Middle East is not devoid of challenges inherent to the region. Particularly, the program would benefit from including an English language course as language might present a barrier for understanding and communicating key scientific concepts. Additionally, adding soft skills and career guidance workshops would maximize the benefits acquired from such a program. Finally, providing accommodations for financial challenges like transportation would be indispensable for the success of such a program.

Next Steps. Currently, an important limitation of the SRI is the absence of a funding scheme to support the program as compared to other similar programs. The program coordinators are continuing to identify ways to make the program financially sustainable, and accessible to students of all socioeconomic backgrounds. Additionally, funding would allow further reach and a wider selection of projects (in engineering groups for example).

An additional limitation is that, to date, AUB is the only institution hosting students in research laboratories. As such, only students geographically close to the university, or those who can commute, are able to participate. A larger number of participating universities would allow the program to expand its reach both in terms of number of students enrolled, and different geographical areas involved. The program coordinators are working on identifying other partner universities to participate in the SRI and begin hosting students.

Finally, the SRI team is committed to continuously improving the quality of the program based on students and mentors' feedback. Regardless of the exact structure of future iterations of the SRI, the success of the first four years indicates the potential for high school students' participation in research projects to develop their skills and spark their interest in STEM and research careers.

ASSOCIATED CONTENT

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

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The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

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ABBREVIATIONS

AUB: American University of Beirut; COP: Community of Practice; LU: Lebanese University; REU: Research Experience for Undergraduates; RISE: Research Internship and Science Education; SAT: Standard Admission Test; SRI: Students as Researchers Initiative; STEM: Science, Technology, Engineering and Mathematics; TIMMS: Trends in International Mathematics and Science Study; UIS: UNESCO Institute for Statistics

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