Early Exposure to Research: Outcomes of the ASTER Certification Program

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This paper discusses a novel structure for providing a high-impact, first-year experience for science students. ASTER (Access to Science Through Experience in Research) is an extracurricular certification program designed to introduce our students to the research culture via seminar attendance, journal clubs, book clubs, and lab visits. Qualitative analysis of the reflective narratives submitted with certification portfolios provided evidence that the program gives students insights into the nature of science and scientific communication, inspires and builds student confidence, deepens understanding of biology, and lends relevance to coursework by linking it to real science and their careers as physicians. In summary, this easy-to-implement, no-cost program provided enriching high-impact experiences for first-year students and reduced their naïveté about research, the goal of ASTER.

It is now widely recognized that high-impact experiences, particularly in the first year of postsecondary education, can have lasting positive effects on student retention and engagement (http://www.aacu.org/leap/hip.cfm). Here we describe a first-year experience that we designed for our particular educational setting, a two-year intensive premedical program that matriculates students into our medical college. Nearly all of our students enter directly from high school and take the Medical College Admissions Test (MCAT) after their first premedical year. Therefore our science-heavy curriculum is taught at an intensive pace that leaves little room in the curriculum to help students develop more broadly as scientists. At the same time, Qatar's national priority is to become an international hub for biomedical research and to create a research culture via Qatar Foundation's major grant agency, the Qatar National Research Fund (2012). This goal is ambitious, given low performance of Qatar's K–12 students on the TIMSS (Trends in Mathematics and Science Study; nces.ed.gov/timss/) and PISA (Programme for International Student Assessment; www.oecd.org/pisa) and low self-beliefs about science achievement (Areepattamannil, 2011). Our challenge has been to retain high-potential students who will continue in our medical program, and also to broaden their interests and reduce naïveté about scientific research very early in their studies.

Many approaches to improve research participation have been advocated. Science faculty are advised to teach courses differently so as to nurture interest in research as a possible career path (Alberts, 2005; National Research Council, 2003). Many creative, effective teaching strategies have been successfully implemented, for example using primary literature (Hoskins, Lopatto, & Stevens, 2011; Wenk & Tronsky, 2011), teaching research skills (Coil, Wenderoth, Cunningham, & Dirks, 2010), and incorporating more investigation in lab courses (Harrison, Dunbar, Ratmansky, Boyd, & Lopatto, 2011). It is hoped that these will lead students to participate in authentic undergraduate research, the effectiveness of which is well-documented (Lopatto, 2007). Here at our institution, similar approaches are being implemented and student research opportunities are plentiful. However, the participants traditionally have been the more ambitious students. We wished to create a structure in which all students could be introduced to the inner workings of research from their first semester in the college. Several years ago, we launched an optional, extracurricular certification program for students who participate in a variety of research-related activities such as attending public seminars and lectures, taking part in journal clubs, and visiting labs. We have named it ASTER, an acronym for Access to Science Through Experience in Research. This paper reports on the qualitative benefits of the program reported by participants and asserts that this high-impact activity provides an efficient, effective structure for introducing students to research from their first undergraduate semester.

Structure of the program

The design of the program was guided by several principles:

- The program should reduce naïveté about research commitments before students seek placements in undergraduate research projects locally and abroad.
- The program offers, and results in, a certification, not an award.

Therefore, it should be doable by all students in a semester without an onerous time commitment.
- The program should be perceived as optional to minimize additional stress and should redirect students' attention from grades to learning. At the same time, it should afford curious students the opportunity to learn and seek avenues to be successful outside of their courses.
- The program should expose students to a wide variety of scholarly activities, not just lab-based biomedical research.
- The program should capitalize on existing activities on campus to promote vertical and horizontal integration and should be easy to administer with minimal faculty time investment, administrative involvement, and cost.

The requirements for certification in any given semester are to:

1. *Witness scientific presentations*. Each participant attends at least two research seminars. After the seminar, the student asks any faculty member present to document attendance with a signature.
2. *Engage in the literature*. Each participant reads and discusses at least two original research articles, one review article or one book about research. This can be in the context of an optional reading in a course, journal club, book club, or personal choice.
3. *Experience science*. Each participant visits any research setting such as a laboratory, clinic, or natural field site for at least one hour.
4. *Give a presentation*. Each participant makes one public presentation. The student arranges to have the presentation video recorded to self-critique it later in the presence of a faculty coach.
5. *Reflect and document.* Each participant submits a reflective narrative about one of his or her experiences. (These narratives provided the data for this study.)

A steering committee of faculty volunteers oversees the program, with one faculty member serving as a *de facto* coordinator. Each fall semester, ASTER is introduced with a class announcement and a broadcast e-mail containing the guidelines and documentation checklist. A student's reply to the e-mail places him or her on a mailing list for reminders and announcements of upcoming opportunities to fulfill requirements. The majority of entering students ask to be placed on the mailing list. Students who complete the requirements request certification by submitting a portfolio on the last day of classes that semester that consists of the signed checklist and "a reflective narrative about one of your experiences." Those who have met the requirements receive a formal certification letter signed by the Steering Committee with copies sent to the Research Office and Coordinator of Student Research. An e-mail of congratulations is broadcast to faculty, staff, and students. To encourage priority consideration of ASTER students for research placements, the list is broadcast again when students apply for competitive summer research internships or for undergraduate research grants. Students are encouraged to seek certification every semester and include their ASTER certification letters in applications for research placements and medical school admission.

Outcomes of participation

In their portfolios, ASTER students documented their participation in a diverse set of activities in each of the categories (Table 1) and chose diverse topics to discuss in their reflective narratives. There was not one type of activity consistently rated as most significant or favorite, nor were there any that were consistently less popular. It is worth noting that those activities in which the student actively participated or took academic risks, such as making presentations to a large audience, were chosen for the narrative more often.

Quantifiable improvement in acceptance rates, GPA, MCAT scores, or research participation was not a goal of ASTER. Given our small, homogenous student body and high participation rates, it is unlikely that a measurable effect of ASTER on these rates could have been isolated from other variables. Therefore we have limited our claims to those themes that emerged from qualitative analysis of the 95 reflective narratives (each approximately one page in length) submitted in certification portfolios over the past five semesters (22, 11, 28, 16, and 18 per semester, respectively). It is important to note that what the students chose to write about for their portfolio was not prompted beyond the guideline to "submit a reflective narrative about one of your experiences." Representative quotes are provided as evidence, although in most cases several students expressed the same sentiment independently. The narratives were not submitted anonymously, so it is possible that students inflated their reports to please the faculty. As a check, we compared them to responses to an anonymous online survey administered during the first year of ASTER for internal evaluation purposes. The fact that the anonymous statements were similar to those in the identifiable narratives validates that the students' comments were trustworthy sources of data for this study. The following sections summarize student feedback about each of the ASTER requirements, followed by our assertions about beneficial outcomes of ASTER participation.

Witnessing scientific presentations

The students' comments made it clear that their first academic research seminars "were too much" and over their heads. This was not unexpected. In fact, the requirement was not meant to increase their knowledge but rather to introduce them to the

discourse of academic science. Indeed, some students commented on becoming aware of the presenter–audience interaction, types of questions asked, and the manner of asking them. In fact, most commented that understanding seminars gets easier over time and that they learned how to manage in such situations:

> I found that this time [in the second semester] I understood much more during the seminars attended this semester than during the last semester. They were no longer stressful or overwhelming.

> Many of my first seminars were like Chinese to me, but I learned to filter out the parts that I understand and make links so that I have a coherent story in my head.

Engaging in the literature

This requirement could be met by participating in journal clubs or book clubs. As expected, students had little high school experience with, or interest in, reading primary or secondary research articles or science nonfiction texts. Consequently, reading primary research articles was especially challenging, but comprehension improved as a result of group discussion. Sessions in which the author of the paper was a guest were especially appreciated. Book club participation required reading books other than textbooks, something the students did not feel they had time for without the structure of ASTER. Reading in a new genre "differed from the intense and dense curriculum we had to go through." Some stated that they had never read science nonfiction and "would never have picked up that book from any library on my own." They even admitted that they originally thought it would be a waste of time and indeed "used to make fun of the people who signed up for [a book club]." Even though the students had diverse purposes for joining the book club, from overcoming shyness to finding a "much needed escape," they indicated that the texts broadened their way of thinking, and primary research articles in particular showed them "the importance of details in answering bigger questions."

Experiencing science

Even for those who in their own words were "always interested in research," the ASTER lab visit was sometimes their first exposure to a lab setting and protocols. This component of the program resulted in "a more detailed idea of what it means to be involved in research." Other comments showed that the participants were able to "connect the lab work with the research work presented in the seminars." An additional benefit was the pride students felt after a lab visit hosted by a technician who had graduated from the national university. Access to the hallowed halls behind locked doors felt like a privilege afforded to professionals and lent seriousness to the experience: [The lab visit] "put me into the atmosphere of professionalism and of following lab guidelines."

Making a presentation

Participants found giving presentations to be an especially valuable experience. Overcoming stage fright and learning to engage the audience made them aware of the importance of oral communication in academia. In addition to the benefits of practicing presentation skills, the participants appreciated being offered a leadership role in class and journal clubs: "The most thrilling part about this [journal club] experience, however, was the presentation itself as

TABLE 1

Examples of documented activities that fulfilled ASTER requirements.

Activity	Examples
Seminars	Monthly seminar series by our own faculty and postdocs, clinical research presentations, Annual Research Forum, Distinguished Lecturers such as David Baltimore, medical ethics lecture on organ donation, social science lecture on politeness across cultures, visiting scientists, Mental Health Day
Journal clubs	Discussion of full papers cited in biology course (e.g., aquaporins review, endothelin, cloning, and characterization of osteoactivin), articles by our own faculty members and postdocs, student-led series on calcium signaling, microtubule assembly, HIV drug resistance
Book clubs	1 to 3 book clubs per semester to discuss books that chronicle ideas and research in biology: *Genome; Why We Get Sick; Stiff: The Curious Lives of Human Cadavers; Immortal Life of Henrietta Lacks; Mountains Beyond Mountains; Good Germs, Bad Germs*
Visit to a research setting	Visit to the genomics core; hands-on experience with tissue culture, western blotting, fluorescence microscopy, experimental design, desert lizard scat analysis, water purification, oocyte membrane recording, and protein quantification; observership in teaching hospital; participation in sleep research of psychology faculty; volunteer assistance with survey research at hospital
Presentation on any topic	Debate club, homework option for biology class (e.g., present research report for the day), presentation to residence halls, copresenter at research conference, International Year of Chemistry *Chemistry in Medicine* competition, presentation on intertextuality in book read for Collegewide Reading Project

Dr. X, the scientist who wrote the paper, was among the audience!" Another participant felt recognized when his presentation became the springboard of a lively discussion:

> My presentation was meant to be an introduction to the journal club, but it led to being more than that. My fellow classmates, the professor and others added information onto the topic that helped me gain more recognition of what I was talking about. It was so interesting that at times it took many minutes to stop a conversation that had been going on. I didn't feel offended by this, but rather I felt glad that my presentation had been a center of discussion.

Emergent benefits

Text from the reflective narratives that gave evidence of insight or growth were coded and categorized by themes, leading us to make the following five assertions about the benefits of ASTER participation:

- ASTER participation deepens understanding of biology and makes coursework relevant (Table 2).
- ASTER experiences yield insights (Table 3) about
  - the nature of science
  - communication in science
  - effort required to do research
  - how experimental systems model biological processes
  - the relevance of research to future medical practice
- ASTER provides opportunities for growth and boosts confidence (Table 4).
- ASTER provides opportunities for new, interesting experiences (Table 5).
- ASTER activities inspire (Table 6).

Conclusions

Students were drawn to ASTER activities for a variety of reasons. The callout e-mail states that ASTER is "one more way to be a star" in the premedical program and that participants "may receive priority consideration for research placements." Some students were frank that "it would look good on the medical school application and it would be really easy to complete." At the same time, many were also motivated by the desire to learn more or in a different way: "In retrospect, I chose to participate in ASTER because I realized that I'd be getting credit for something I had already decided on doing. I wanted experience outside of textbooks, which is exactly what ASTER would allow me to do." The

TABLE 2

Assertion 1: ASTER participation deepens understanding of biology and makes coursework relevant.

Cited activity	Representative quotes from ASTER portfolios
Journal club	This discussion was in unison with what we recently covered in neuroscience with regard to Goldman equations and Nernst equations. . . . [T]his knowledge was not new to me but in fact it was only the lengthy discussions of journal clubs which gave me a comprehensive understanding of the material. We had just finished learning briefly about the function of aquaporins as "water channels" in biology lecture, and my view of these channels was very simplistic.
Book club	The book [*Why We Get Sick*] in a large way revolutionized or broadened my thinking. . . . Earlier I couldn't have cared less about the exact reactions that occur in the Krebs' cycle/Calvin cycle or . . . . Now, however, I see that such details arise in biology when individuals try to answer bigger questions. . . . An excellent example . . . is the problem of allergies. . . . This way of thinking evolutionarily about life questions makes us inquisitive and gives us a reason to go into details of proximal causes and processes so that we may answer the bigger problems. [Re: *Genome*] "Genes are not there to cause disease," Ridley wrote in his book over and over again.
Seminar	The seminar discussed the sequence of events related to the hemoglobin switching that occurs as we progress through different stages of our lives. . . . When I saw the phrase "sickle cell anemia" I thought to myself, "Hey, I know that . . . finally something I can relate to." Ironically that wasn't the case. I was fascinated by the amount of material I couldn't even grasp. [At Research Retreat poster session] I was surprised to find out how much I actually understood. It was also interesting to note how some of the ideas and techniques that we had learned in biology were used in certain studies.
Presentation	[Regarding his presentation about surfactants when studying human respiration] How does evolution adapt organisms like humans to have evolved a complex mixture of molecules aimed a reducing the surface tension of the liquid on alveolar surfaces? It's fascinating to make predictions as to what kind of molecules one would expect to find, and when one's predictions are confirmed— pure exhilaration follows.
ASTER	As a premedical student I had a superficial overview of what science is really about. Science is not simply information I have to know in order to pass my exams and get good grades; it is about wanting to know more and more in order to build up the big picture. It is like what my biology professor once said, "Do not learn biology for your grade's sake; learn biology for biology's sake."

TABLE 3

Assertion 2: ASTER experiences yield insights about scientific research.

Insights about	Representative quotes from ASTER portfolios
The nature of science	*Journal club:* The article . . . besides deepening my understanding, also made me question the credibility of what we are taught every day. *Book club:* In particular we explored how scientists think and how theories in science develop continuously as new evidence becomes available. It was also interesting to learn how different scientists interpret the same evidence and reach different conclusions . . . *Lab visit:* The antibody and protein levels were then measured using western blotting techniques to get an idea of the efficiency with which the gene was transcribed. . . . I learned how research is extremely particular; there are so many methods of checking and cross-checking used to ensure that the desired protein is being studied and also to minimize the subjective interpretation of results. *Presentation:* Probably the most innovative and interesting thing about the procedures was how the researchers identified if DNA repair occurred or not. . . . Now I understand what being "creative" in lab means. *ASTER:* In the process of fulfilling the ASTER requirements I discovered as a student that scientists are not near to cracking all the processes of life around us, and that there is still a lot to learn.
Communication in science	*Journal club:* Another beneficial experience learned from journal club participation is how important discussion is in science. A research paper is simply a global journal club where scientists or researchers share their ideas. *Seminars:* It is also very important when a person presents the results of his or her study to present it in different forms and to present it as it is without altering the data to suit one's expectations . . . [as] in the seminar on the models of schizophrenia presented by Dr. X. *Presentation:* I consider the public presentation to be the most important part of ASTER as it made me realize that science is a social activity . . . *Presentation:* Walking out of there, I felt like the information I collected deserved further elaboration and explanation. I ended up with a newfound sense of respect and appreciation for anyone who presents a lecture or presentation about anything, especially if they have a lot to say about that particular subject.
Effort required to do research	*Journal club:* A scientific paper only a few pages long could require hundreds of calculations and numerous trials to produce. Many researchers must also accept the possibility that their research may fail or produce insignificant results. Therefore I consider researchers to be dedicated risk-takers. *Seminar:* [At the Research Forum] In her presentation . . . Dr. X stated that it had taken them quite a while just to establish the basis and control for the student and that after approximately 2 years they had just reached the end of the preliminary stage. The amount of time that goes into planning a study was not [something] I had previously thought about. *Seminar:* As he explained the process of synthesizing his first molecule, he mentioned that it required 32 steps, each involving complicated chemical mechanisms. Although I wasn't familiar with the details of the chemistry involved, I did grasp much of what he was saying and was left stunned to learn how complicated the process truly is, how much time, thought and effort was necessary . . . *Presentation:* One of the insights that hit me was that research is a LOT of work and is not all that exciting at times.
Experimental model systems	*Journal club:* I also realized the significance and importance of the frog ovum in research! *Journal club:* It is confusing to me how scientists transfer the internal environment of body cells into a lab container. *Book club:* After reading *The Immortal Life of Henrietta Lacks*, I realized that oftentimes while working in the lab, we usually view different cells as tools or objects of interest in research but fail to notice that they actually belong to someone who was alive. *Seminars:* . . . when he clearly pointed out that not all models on rats supported the predicted symptoms of schizophrenia on humans
Relevance of research to future medical practice	*Book club:* [Re: *Henrietta Lacks*] This was interesting and insightful for me, as a future doctor, to know about the past treatment of patients and misuse of the patient's vulnerability as I might come across something similar in my life. *Book club:* [Re: *Why We Get Sick*] The book will also, hopefully, end up making me a better doctor since I now realize that, often, what is considered a disease is actually a natural defense of our body. An example . . . is that of morning sickness . . . a mechanism the mother's body uses to protect her fetus… *Presentation:* I think that this article [about water purification by dialysis] was not only important from a chemist's point of view, but also from a medical doctor's perspective. . . . Due to the catastrophes like the tsunami in Indonesia, flood in Pakistan, etc., the water in many of the devastated areas become contaminated.

structure afforded by ASTER provided enough motivation to spend a bit of extra time on low-commitment, short-duration tasks such as reading an article or visiting a lab. A number of students emphasized that completing the requirements was not labor intensive but gave them a sense of accomplishment. Although one student initially felt that "ASTER seemed to be a never-ending task," looking back at her portfolio she was surprised to find that "the whole thing doesn't even take 24 hours." Overall, many shared the sentiment expressed by the statement, "I feel pleased at the fact that it was indeed very simple to complete and doubly pleased at the fact that I actually enjoyed a lot of it."

With only about 50 incoming students per premedical class, almost all our students participate in at least some ASTER activities in their first premedical year. Furthermore, applications for research participation on and off campus have always been high, and the acceptance rate of our premedical students into medical school is high (recently >80%). Therefore we did not aim to determine whether ASTER certification correlates with improved MCAT scores, medical school acceptance, or research placements. However, it can be concluded that ASTER has been achieving its goal of improving the academic culture in our college. It has given participants a better understanding of what is involved in joining a research community and inspired them to look for a link between what they learn in class and the research that builds on this basic knowledge. This happened by encouraging participation in existing opportunities, a small amount of effort on the part of both students and faculty and no cost. ASTER also provided a framework for scientists, physicians, research staff, and librarians to offer informal hands-on experiences related to their research interests. The fact that many participants continued attending seminars even after their requirements were met is testimony to the success of the program.

> [ASTER] was very close to slipping me by. So I really thought before the semester that I didn't like research, I thought it must be a very boring job just staying in the lab all day and didn't want much to do with it. Then I was introduced to ASTER and thought, Nah, I can probably be part of something more exciting, why choose this? Then everyone was talking about it and doing it and saying it will give us opportunities in the future so I just went with the flow and decided to do it. Little did I know how much I would actually enjoy fulfilling all the requirements . . . I am excited to do it in the future: more seminars I only understand half of, more books about dead bodies to read, more work preparing a presentation. . . . Sounds fun, doesn't it? For me, yes, actually, it does.

Perhaps the best evidence that ASTER has improved the academic culture is that former ASTER students launched their own sponsored student research club whose primary activities mirror those of ASTER: they host journal clubs, organize lab visits, and provide presentation opportunities. They have invited the student research coordinator of the medical faculty to be their club sponsor, thus formalizing the vertical integration of the college's researchers with the premedical unit. For these reasons we consider the ASTER initiative a success and en-

TABLE 4

Assertion 3: ASTER provides opportunities for growth and boosts confidence.

Cited activity	Representative quotes from ASTER portfolios
Journal club	I found that this time [in the second semester] I understood much more during the seminars attended this semester than during the last semester.
Book club	I had some truly amazing insights about science during the reading of the assigned books . . . the most rewarding sensation was when I would discover that someone had already suggested and tried this particular approach before me. It gave me the satisfaction that I was thinking in the right direction, and hence helped develop my critical reasoning abilities.
Seminars	Now that I have completed ASTER, I find myself checking my schedule for free time when I can actually attend a seminar I think is interesting, which is not something I would have done regularly before ASTER.
Presentation	My favorite activity was the chemistry presentation competition. It was a huge event and it was a great opportunity to take part in it. The hardest part in it was being under pressure as a student who is representing Cornell. I was sitting among the audience during the high school sessions and heard some people saying, "Let's wait to see [the pre-med] students. They gotta be different!!" That was a lot of pressure to meet people's expectations. . . . Although I am on the debate team and I used to give presentations before, this one influenced me the most and enforced my confidence. By requiring me to discuss my speech with a professor, ASTER has provided me with a string of hope. It has made me realize that I can speak in public and that I can do so in a charismatic fashion. It has made me realize that I am able to convince people of my future scientific discoveries and to convince my patients and colleagues, in the future, of the liability of certain treatments. . . . I now feel a lot more confident.

courage others to consider a certification structure into which enriching high-impact, faculty-led extracurricular experiences can be integrated. We can imagine many ways the ASTER model can be adapted for other types of programs and institutions. ■

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TABLE 5

Assertion 4: ASTER provides opportunities for new, interesting experiences.

Cited activity	Representative quotes from ASTER portfolios
Lab visit	She handed us a sample of lizard feces . . . to identify what our lizard had eaten. It was a bit awkward in the beginning but I [came] to enjoy it as the feces samples started to show more and more identifiable [parts of its diet]. When I went to the lab visit, I was amazed by all these facilities here in Weill Cornell. There is another world hidden in [our school] [that] even a student in Cornell, me, was not aware of it (embarrassing isn't it?).
Book club	The [*Stiff*] book club, to me, would have been less interesting to attend if the humor and easy-to-understand information were not there. The most engaging aspect of [*Genome*] was not necessarily the content, rather the author's ability to present the content in such a way that it seems immediately relevant to our lives as a whole.

TABLE 6

Assertion 5: ASTER activities inspire.

Cited activity	Representative quotes from ASTER portfolios
Journal club	More than anything else, the journal club awakened in me a desire to generate knowledge. . . . This journal club went a long way in encouraging me to work in a research project of my own with Dr. X.
Book club	This book proved to me the quote that says, "Our deepest fear is not that we are inadequate. Our deepest fear is that we are powerful beyond measure. . . .We ask ourselves, Who am I to be brilliant, gorgeous, talented, fabulous? Actually who are you not to be?" by Marianne Williamson. Who are we to not be the "Paul Farmers" of the world?
Seminar	It was indeed magnificent. I didn't understand much but for a moment there I stopped and stared, thinking to myself, "That could be me one day." The seminar also reminded me I have a long way to go. Having a chance to meet a Nobel Prize winner was wonderful.