

Research Article

The Asthma Immersive Research Experience (AIRE) Program: Paving the Way for Future Scientists

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Abstract

The global decline in health science researchers underscores the need to build research capacity early, as undergraduate research participation is associated with greater research self-efficacy, development of transferable skills, and sustained interest in medical and scientific careers. However, traditional short-term, project-based summer research programs may be less accessible to students with limited prior research experience. In response to this need, a hands-on undergraduate research program was developed to provide early exposure to clinical and laboratory-based research. The Asthma Immersive Research Experience (AIRE) program was launched in Fall 2021 with the goal of delivering meaningful research training to undergraduate students interested in medical and scientific careers. AIRE provides practical experience in asthma and allergic disease research within an academic children's hospital setting, combining laboratory work, direct engagement with research participants and families, peer and faculty mentorship, a structured seminar series, and continuous student feedback for program improvement. The program emphasizes team science and collaboration while exposing trainees to a broad range of career pathways, including physician-scientists, basic and translational researchers, biostatisticians, epidemiologists, geneticists, bioinformaticians, nurses, full-time research assistants, and clinical research coordinators. To date, 45 students have enrolled in AIRE, with 82.1% returning for multiple semesters, reflecting strong engagement and program retention. AIRE alumni are currently enrolled in medical school (45.8%) or graduate school (12.5%), employed as clinical research coordinators (8.4%), or actively pursuing admission to medical or graduate programs (33.3%). Together, these outcomes highlight AIRE as an effective and inclusive undergraduate research model that promotes sustained engagement and successful progression toward medical and scientific careers.

Keywords

Undergraduate Research, Health Sciences Education, Mentorship, Team Science, Career Development

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1. Introduction

The number of medical and health sciences researchers has declined worldwide [1]. Building research capacity among undergraduate health sciences students has been identified as a crucial intervention to address this decline [1]. Actively participating in research as a student has been linked to higher research self-efficacy and competence levels [1], fostering a lasting interest in scientific careers. Cultivating a robust research culture can inspire and prepare undergraduate students for future careers as scientists and physician-scientists. Hands-on academic research is a particularly valuable experience for undergraduates, as it teaches transferable skills such as communication, critical thinking, and information literacy, and can influence their decision to pursue an academic research career (<https://www.cur.org>) [2]. Students gain more from research than standard lab courses, and research labs benefit from student contributions and mentoring opportunities [2] (<https://www.cur.org>).

In recent years, there has been growing recognition of the importance of structured, immersive, and longitudinal undergraduate research experiences as high-impact educational practices. Course-based undergraduate research experiences (CUREs) have emerged as scalable models that broaden student access to authentic research while maintaining meaningful engagement. Recent studies demonstrate that participation in such structured research experiences is associated with increased student interest in science, improved academic performance, and sustained persistence in STEM pathways, particularly when compared to traditional lecture-based approaches [3, 4]. Longitudinal analyses further indicate that sustained engagement, mentorship, and opportunities for project ownership are critical drivers of science identity formation, research self-efficacy, and long-term career commitment [4].

Parallel to the growth of CURE-based models, there has been increasing emphasis on longitudinal and multi-semester training programs that extend beyond traditional short-term experiences. Emerging evidence suggests that longer-duration engagement allows students to develop deeper technical skills, integrate into research teams, and gain a more comprehensive understanding of the research process. Evaluations of clinical and translational research training programs for undergraduates demonstrate that structured exposure to research environments enhances career readiness, confidence, and successful transition into biomedical and clinical research pathways [5]. These findings underscore the importance of sustained, iterative learning approaches that support progressive skill development over time.

Additionally, immersive and clinically integrated research programs, particularly those embedded within academic medical centers, provide a unique and increasingly recognized model for undergraduate training. Clinical immersion experiences expose students to the real-world interface between research and patient care, enhancing professional communication skills, interdisciplinary collaboration, and understanding

of translational science [6]. These programs also help students contextualize how scientific discovery informs clinical practice and how clinical observations generate research questions.

Traditionally, undergraduate research programs offer students the opportunity to work on a defined laboratory project in the summer, usually lasting 8-10 weeks. While valuable, this structure can be challenging for students with little or no prior research experience who may not yet feel prepared to take on a project independently. Therefore, it is necessary for academic institutions to create local programs that are accessible and offer hands-on research experiences, making the concept of research tangible so that young future scientists can imagine a career path that includes scientific discovery. Indeed, an increasing number of universities call on faculty to enrich the undergraduate curriculum by providing impactful research opportunities for enrolled students [7], but programs are scarce often due to a lack of funding.

2. Methods

2.1. AIRE Rationale

In response to this need, the Asthma Immersive Research Experience (AIRE) Program was developed in the Division of Asthma Research at Cincinnati Children's Hospital Medical Center (CCHMC). The AIRE Program provides students with directly integrated laboratory and clinical research opportunities that align with ongoing research projects within the Division. Experiences range from participating in clinical research visits to engaging in in-depth laboratory bench work, giving students exposure to the full spectrum of clinical and translational research, basic research, epidemiology, and statistics.

2.2. AIRE Program Design

Designed as a year-round program, AIRE allows students to participate for multiple semesters, enabling them to explore new studies and/or to pursue sustained, deeper engagement with an existing project. AIRE was intentionally designed as an alternative to short-term summer research models. Instead of completing a given project within a brief timeframe, students join active research teams for two or more semesters, allowing sustained immersion in the full research process. As they become integrated into the team's work, students build confidence and make meaningful contributions to a highly productive research team.

The program emphasizes intensive mentoring and intentional career exploration, grounded in the belief that meaningful research engagement depends on attentively listening to student perspectives and responsively adapting program design. Accordingly, AIRE systematically solicits, evaluates, and incorporates student feedback as a central mechanism for continuous program improvement. At the end of each semester, students

deliver a brief presentation summarizing their research experience, reinforcing both communication skills and scientific understanding. Collectively, these elements create an immersive, meaningful, and rigorous first exposure to research.

The AIRE program was formally launched in Fall 2021 through a partnership with the University of Cincinnati. Students apply to the program and, if accepted, participate either as volunteers or for academic credit (typically 2–3 credit hours). All students commit 10–12 hours per week (minimum) to their AIRE research activities. Program materials, including the AIRE Handbook, Program Summary, Recruitment Email, Application Questions, Student Participation Agreement, and Program Feedback Survey, were submitted to the CCHMC's Institutional Review Board (IRB) under Protocol ID No. 2025-0676. The IRB determined that this submission does not constitute human subjects research as defined by DHHS and FDA regulations.

2.3. AIRE Academic and Clinical Training Environment

The AIRE program is based within the Division of Asthma Research at CCHMC, a leading pediatric academic medical center with a strong emphasis on research, education, and clinical excellence. As a primary teaching hospital affiliated with the University of Cincinnati's College of Medicine, CCHMC provides an immersive academic environment in which research, interactions with study participants and families, and medical education are tightly integrated. This setting allows undergraduate trainees to experience firsthand how scientific discovery informs clinical practice and how clinical observations drive research questions. Housing the AIRE program within a children's hospital offers a particularly valuable training context, as students are exposed to pediatric populations,

family-centered care, and ethically grounded research practices early in their academic development. Students interact with clinicians, physician–scientists, research coordinators, nurses, and allied health professionals, gaining a comprehensive understanding of team-based translational research within a real-world healthcare setting. The close proximity to medical students, graduate students, postdoctoral fellows, and faculty further reinforces an academic culture that emphasizes mentorship, inquiry, and professional identity formation.

This integrated academic–clinical environment distinguishes AIRE from traditional undergraduate research programs by providing sustained exposure to the culture of a medical school–affiliated research enterprise. As a result, students can contextualize their research experiences within broader pathways toward careers in medicine, biomedical research, and health-related sciences.

2.4. AIRE Program Administration

The structure of the supporting faculty and administration was carefully constructed to provide a rigorous and supportive experience in a collaborative setting. As such, the AIRE program is directed by two faculty members (who also serve as AIRE mentors), each with a specific background that fosters laboratory or clinical expertise, including an epidemiologist and a basic laboratory scientist. Additional faculty serve as AIRE mentors, including physician–scientists and faculty with backgrounds in molecular and cell biology and immunology. The supporting staff also includes six research assistants, eight clinical research coordinators, two nurse practitioners, two registered nurses, and administrative support. This diverse team provides students with exposure to a wide range of expertise and backgrounds, enhancing their understanding of both basic science and clinical research (Figure 1).

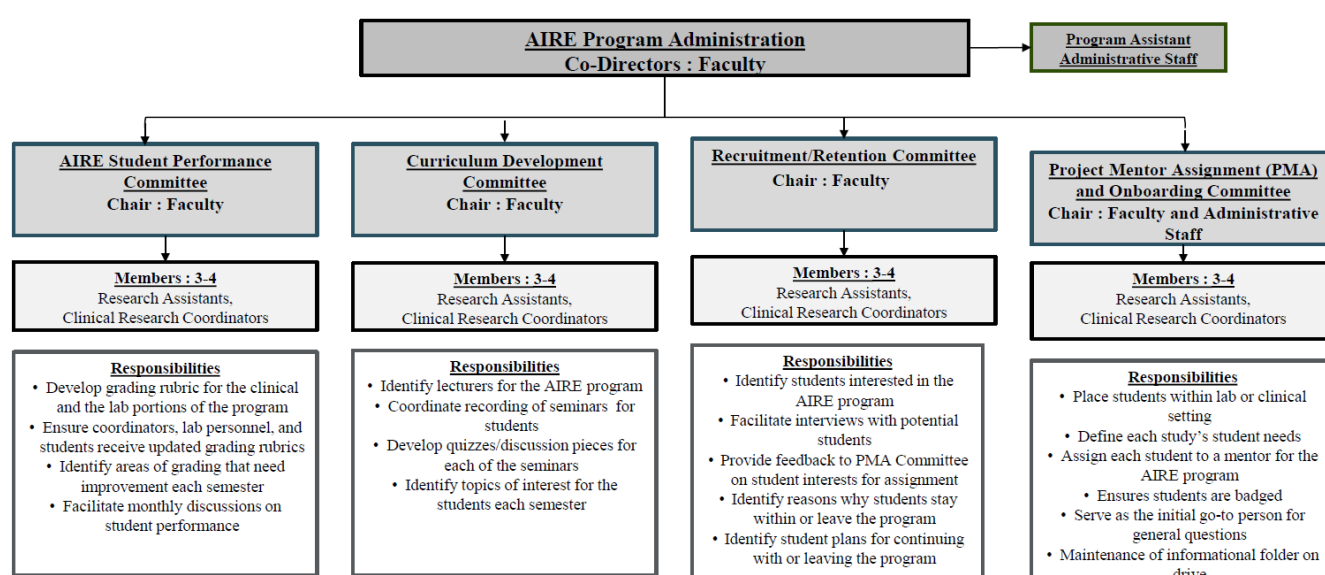


Figure 1. Flow Chart of the Administrative Structure of the AIRE Program. This flow chart outlines the administrative structure of the AIRE program, detailing the various committees and their respective responsibilities.

2.5. AIRE Program Admission Process

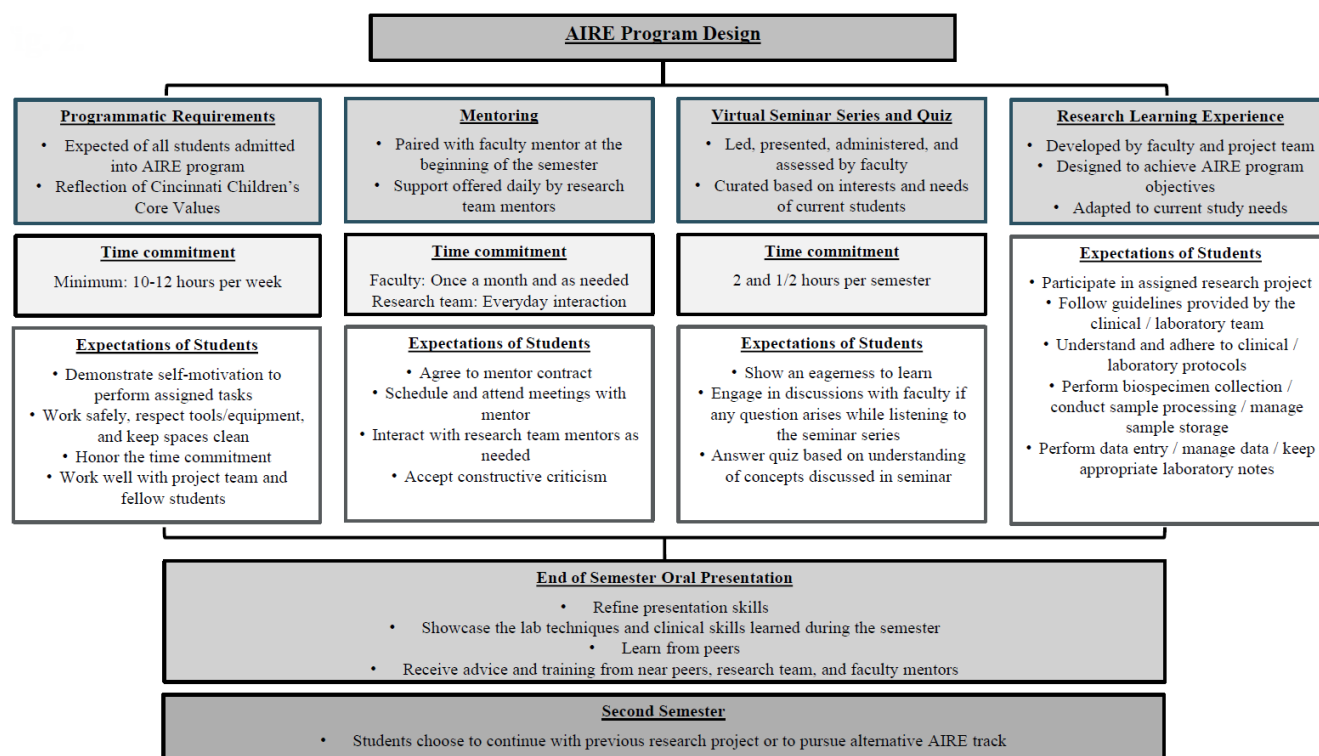


Figure 2. AIRE Program Design. The Figure outlines the programmatic requirements, including mentoring, the virtual seminar series with associated quizzes, and the research learning experience. It also enumerates student expectations within each of these categories and highlights the requirement for end-of-semester oral presentations.

Figure 2 provides an overview of the AIRE program design from application to the end-of-semester presentation. The AIRE application contains 17 questions designed to gather information about the applicant's area of interest (laboratory-based or clinical research), time commitment, and availability, as well as their demographic details (including race, sex, gender, and ethnicity). Applicants are also required to submit an unofficial transcript, a resume or Curriculum Vitae, and a brief personal statement outlining their research interests and future goals. Incomplete applications are not reviewed. Students who apply are eligible for consideration if they meet the minimum requirements (GPA >3.0 and a commitment of ≥ 10 hours per week to their AIRE research). Applications that pass these requirements are then reviewed to align their personal goals with AIRE's mission and with the laboratory team or one of the clinical research projects. The number of new students invited to join the AIRE Program each semester is determined by study capacity at the beginning of each semester, ensuring students have adequate support and a meaningful research experience.

2.6. AIRE Program Research Tracks

The AIRE program offers two tracks: a clinical research

track and a basic science (wet-lab) research track. Students select their preferred track when they submit their application. Students who choose the clinical research track are interviewed by faculty, clinical research coordinators, and research nurses. Students who choose the laboratory track are interviewed by faculty along with research assistants. Students are paired with an appropriate faculty mentor based on their chosen research track.

In the clinical research track, students participate in clinical research visits, gain patient-facing experiences, and learn about Good Clinical Practice, adherence to research protocols, research visit preparation and conduct, data and sample collection techniques, informed consent, participant contract and recruitment, data entry, data analysis, and sample processing techniques. In the laboratory track, students are exposed to cutting-edge research techniques, including basic and translational methods such as cell culture, molecular biology, immunology, microscopy, data analysis, and *in vitro* and *in vivo* models. All AIRE students are offered the opportunity to participate in clinical shadowing to gain insight into the medical profession and allied health careers. Through both tracks, students gain valuable insights into team science via an interdisciplinary, collaborative approach.

While students focus primarily on their chosen track, they are also exposed to the other track as part of their curriculum.

This cross-observational experience is integral to the program and allows students to further explore their curiosity through exposure to opportunities available only by engaging in the alternate track. Often, this cross-exposure sparks interest in pursuing the other track.

2.7. AIRE Seminar Series

The didactic portion of the AIRE program consists of a virtual seminar series. This seminar series was created and is presented by faculty experts across CCHMC. The topics discussed in these sessions include the benefits and challenges of clinical research, hypothesis development, research ethics, data integrity, scientific rigor, data management and analysis, translational research, and health-related research career exploration. After each seminar, students complete a quiz to assess their understanding of the concepts presented. Timely feedback is provided to program administration to support the identification of areas for curricular optimization and improvement, ensure that students remain engaged in the learning experience, and provide a mechanism for assessing student development.

2.8. AIRE Mentorship and Career Exploration

An integral part of the AIRE program is its emphasis on mentoring, as the benefits of effective mentorship are well established [7-10]. During AIRE enrollment, students are paired with a faculty mentor. Working with a faculty mentor outside of standard coursework has been shown to positively impact students' interest in, preparedness for, and actual pursuit of graduate study and professional careers in the health sciences [11, 12]. Therefore, AIRE students are paired with a faculty mentor based on their interests. These mentor-mentee pairs meet monthly to discuss their learning experiences, whether their expectations and goals are being met, and if any deficiencies need to be addressed. Mentors also help guide the students to the AIRE track that best aligns with their research interests, often encouraging and facilitating participation in both tracks. Finally, mentors frequently guide students with their applications to graduate or medical school by reviewing their resumes and assisting in interview preparations. Students also receive mentorship from other AIRE faculty, clinical research coordinators, research nurses, pediatric nurse practitioners, research assistants, graduate and medical students, and post-doctoral fellows, providing a variety of insights into multiple career paths and individual experiences (Figure 1).

In addition to faculty mentors, the AIRE program fosters peer mentoring, as the benefits of peer learning are well known [13, 14]. Group and individual discussions are organized between AIRE students and current Ph.D. and MD/Ph.D. students. Career exploration pathway discussions are also organized, bringing together faculty, staff, and students to share their career journeys. This allows AIRE students to access

near peers, providing an opportunity to discuss their future career paths, the hurdles they may face, the decision-making process for graduate school, graduate and medical school applications, and other relevant topics. The AIRE program also provides informal opportunities for mentoring and career exploration by fostering community building through social gatherings, including divisional social activities [15, 16].

2.9. AIRE End-of-Semester Presentations

At the end of their AIRE semester experience, students are required to give an oral presentation to the AIRE faculty and staff. The presentation allows the student to showcase their verbal communication skills and summarize their research experiences during the semester. This experience, guided by near-peer mentors, helps them learn scientific presentation and communication skills, including how to clearly and concisely explain their research, which will be invaluable as they apply and proceed to graduate or medical school. Another key advantage of these presentations is that they expose students to research conducted by their peer AIRE students. This experience offers a platform for other students to give feedback and share ideas, potentially inspiring students to pursue alternative skills and experiences in subsequent semesters [16, 17].

2.10. AIRE Grading

AIRE faculty mentors and staff meet quarterly to discuss student progress and performance. The individual study and laboratory staff also provide qualitative feedback to AIRE faculty mentors every 2 weeks. The AIRE Program developed a rubric for grading AIRE students (Figure 3). AIRE students are graded on 20 components, which include: 11 general components, 2 AIRE Program Requirements (Figure 3A), and 7 track-specific components (Figure 3B). Students receive a grading rubric and qualitative feedback at the end of each semester. Final grades are also submitted to their respective departments when the course is taken for academic credit.

2.11. AIRE Feedback Survey

The AIRE feedback survey is administered through the Research Electronic Data Capture (REDCap) system, with the survey link distributed to students at the completion of each semester. Responses are collected confidentially, and all data are analyzed in a de-identified manner without revealing student identities. Survey results are aggregated and reported as percentages based on the responses received (Figure 5).

2.12. Statistical Analysis

Student career trajectory proportions were stratified by AIRE track (Clinical vs. Basic Science) and compared using Fisher's Exact Test. Survey results were visualized using Likert Graph using the *likert* package in R. Statistical significance is defined at $p < 0.05$.

a		b	
General AIRE Components		Clinical Research Track	
1	Exhibits the CCHMC Core Values	1	Observes and understands informed consent
2	Maintains accountability and integrity	2	Administers study questionnaires
3	Wears appropriate attire	3	Performs biospecimen collection
4	Maintains required attendance and punctuality	4	Adheres to and understands research protocol
5	Shows initiative and effort	5	Performs data entry
6	Accepts constructive criticism	6	Prepares for clinic visits
7	Exhibits professional language and communication	7	Engages with participants and families
8	Works safely and takes care of tools/equipment/office space	Basic Science (Laboratory) Research Track	
9	Exhibits a respectful demeanor and interactions with all Division members	1	Exhibits safe laboratory techniques
10	Is responsive to feedback	2	Conducts sample processing after fully trained on the procedures
11	Limits cell phone use in the lab and during visits	3	Adheres to Research protocols and performs DNA/RNA extraction on various samples collected
AIRE Program Requirements		4	Laboratory sample management and storage
1	Submitted seminar quizzes on time	5	Maintain clean laboratory workspace
2	Performed shadowing requirement	6	Follows appropriate electronic Lab notebook and/or personal notebook keeping
		7	Laboratory data management
		Qualitative Feedback:	

Figure 3. Grading Rubrics for the AIRE Program. (a) The general rubric used for grading students applies to both clinical and lab research courses throughout the semester. (b) The specific rubrics for grading and providing feedback to the students enrolled in the clinical research track and the basic science (laboratory) research track.

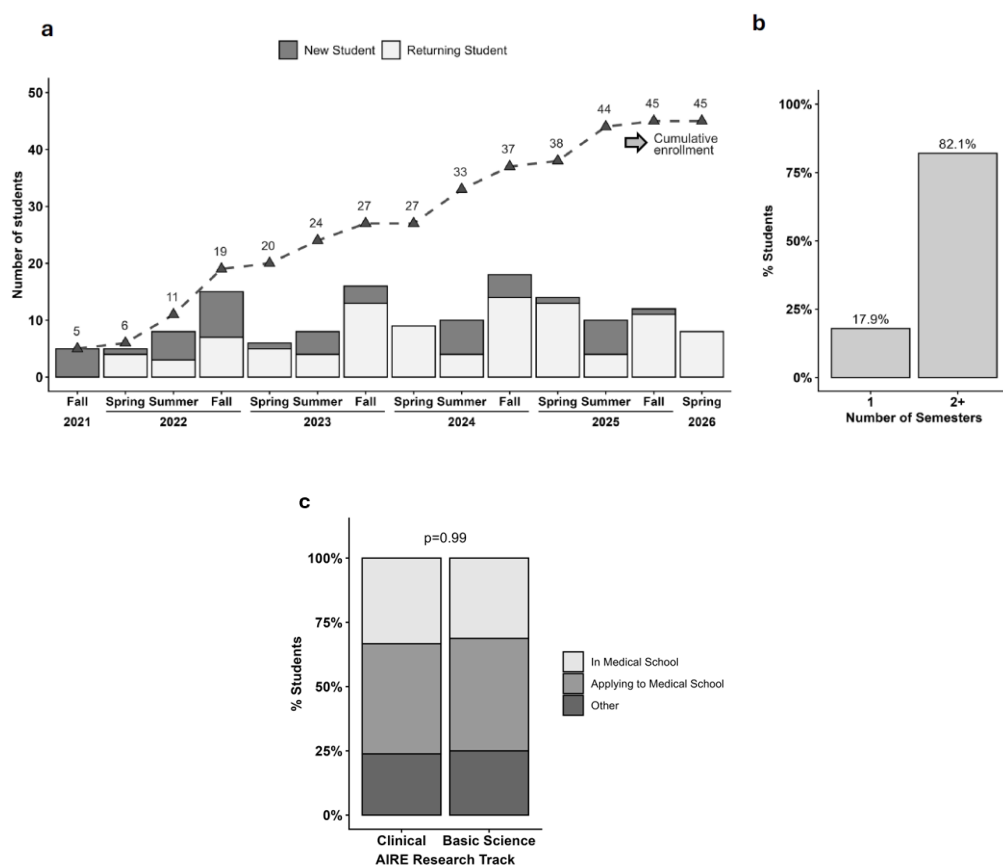


Figure 4. Student Enrollment, Retention, and Career Trajectories in the AIRE Program. (a) Student enrollment in the AIRE program over time. The consistent growth in the number of enrolled students highlights interest and engagement in the program. (b) The percentage of students based on the total semester enrolled in the AIRE program. This highlights the program's 82.1% return rate, indicating that a significant majority of students return for more than two semesters. (c) Career trajectories by AIRE research track (Clinical and Basic Science). Career outcomes were similar across both tracks, with students from each group pursuing science-oriented career paths.

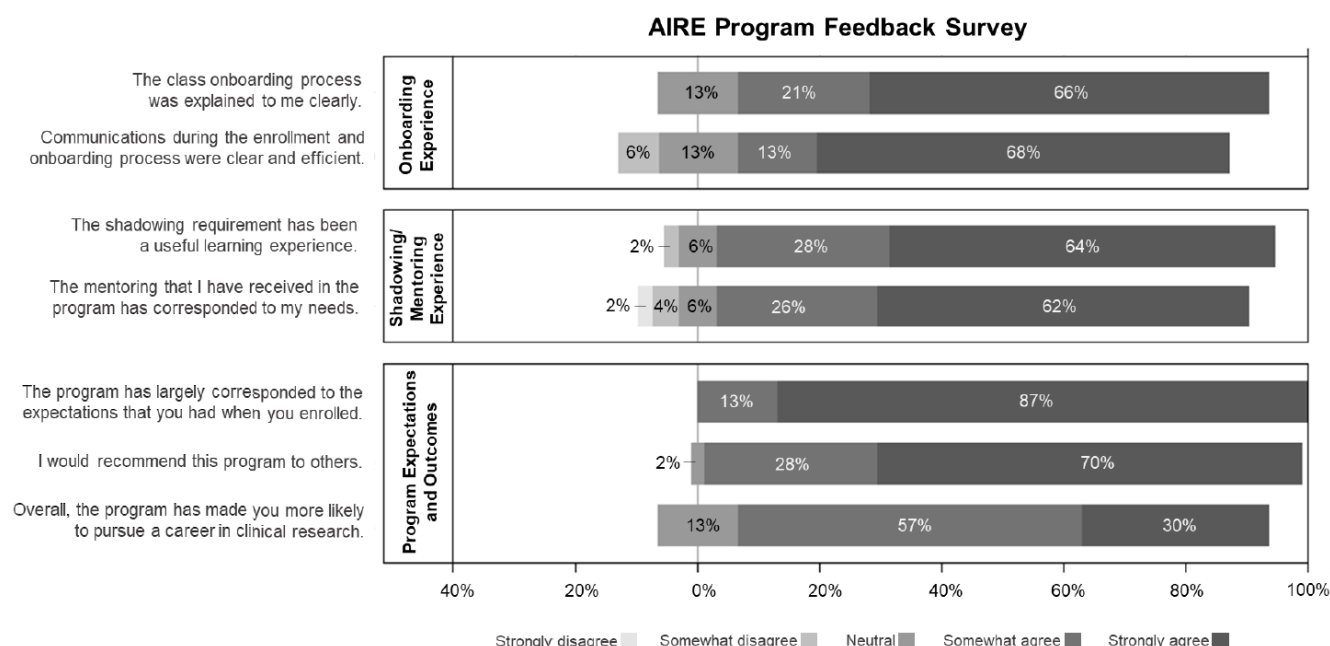


Figure 5. AIRE Student Survey Results. A survey was administered to forty-five students in the AIRE program. The results indicate that, except for shadowing/mentoring experience and onboarding experience, which received some "strongly disagree" and "somewhat disagree" responses, most students "somewhat agree" or "strongly agree" with the program's expectations and outcomes.

3. Results

3.1. AIRE Program Outcomes

A total of 45 students have participated in the AIRE program thus far (Figure 4a). Of the 45 past and current AIRE students, 44.4% identified as White, 31.1% as Asian, 6.7% as Black, 6.7% as mixed-race, and 11.1% as Other. Additionally, 86.7% of the students self-identified as female. Between the fall of 2021 and the summer of 2025, 82.1% of AIRE students completed ≥ 2 semesters (Figure 4b), reflecting strong student satisfaction with the program and a desire for continued engagement.

Among the 45 AIRE students, 29 have completed their undergraduate degree, and these graduates were surveyed with two questions regarding their career trajectories. The questions were: 1) "What are you currently doing in terms of job or career?" and 2) "Are you planning to pursue a PhD, master's degree, or attend Medical School in the future?" Responses from 24 (82.8%) students were collected. Of these, eleven (45.8%) are in medical school, eight (33.3%) are applying to medical school, two are in graduate school, one is in physician assistant school, one is applying to optometry school, and one is applying to graduate school. Of the eight applicants applying to medical school, two are currently employed as Clinical Research Coordinators at CCHMC. An AIRE alumna currently in medical school returned to the division to complete a summer project through the Medical Student Scholars Program (MSSP), inspired by the research ex-

perience she gained during her time in AIRE. The career trajectories were similar between the Clinical and Basic Science AIRE Research tracks (Figure 4c). In both groups, approximately 30-35% of students were enrolled in medical school, 40-45% were applying to medical school, and 20-25% were pursuing other paths. There was no significant difference between tracks, indicating comparable progression toward careers in science ($p = 0.99$).

Students who have been part of the AIRE program for more than two semesters may request to conduct their capstone research project through AIRE, subject to faculty availability. To date, six students have successfully completed capstone projects within the AIRE program, and they present their projects as posters at a capstone symposium. Two of these students received awards for their capstone research from the University of Cincinnati Undergraduate Scholarly Showcase and Symposium, underscoring the rigor and excellence of the AIRE program.

3.2. AIRE Student Feedback

Feedback from AIRE students was solicited on key aspects of the program at regular intervals, including onboarding, mentoring, research experiences (with attention to breadth of exposure and usefulness), and overall fulfillment of expectations. Surveys were administered to both current and former AIRE students (Figure 5). Overall, student feedback was highly positive across all domains. For the onboarding experience, 87% of students either strongly or somewhat agreed that the onboarding process was clearly explained, and 81% agreed that communication during enrollment and onboarding

was clear and efficient. Responses regarding the shadowing experience were particularly strong, with 92% of students agreeing it was valuable. Similarly, 88% of students reported that the mentoring they received aligned well with their individual needs. Satisfaction with the program was exceptionally high: all respondents indicated that the AIRE program met their expectations, and 100% agreed they would recommend it to others. When asked specifically whether they would recommend AIRE to fellow students, 98% responded positively. In addition, 87% of students reported that participation in AIRE increased their likelihood of pursuing a career in health-related science. Qualitative feedback is summarized in [Table 1](#). Collectively, these results suggest that participation

in AIRE has meaningfully informed students' decisions to pursue careers in science, likely driven by the program's positive educational, mentoring, and experiential opportunities.

Collectively, the AIRE outcomes and feedback provide valuable information to continue optimizing and improving the program going forward. To further improve the mentoring experience, the number of times students meet with their mentors will be increased, and a program handbook will be created, including validated student-mentee-mentor contracts. The program staff is committed to offering a wide variety of experiences that foster a diverse and inclusive scientific community [18].

Table 1. Written quotes provided by the students when completing the AIRE survey.

Some of the quotes from the AIRE program students

- 1) I have really enjoyed my time in the AIRE program and have had a great learning experience.
- 2) Overall, I think it has been great to watch the AIRE program grow. While I understand it is hard to get everyone together, I thought the introductory meeting was very important as it allowed all students to meet and connect.
- 3) I think the program is going exceptionally well. The AIRE program has made me fall in love with the lab and research. Everyone is so kind and helpful.
- 4) Give students an opportunity to potentially be paid if they have been working in the lab for a certain amount of time.

4. Discussion

Our results demonstrate that AIRE program has successfully engaged undergraduate students in rigorous, hospital-based academic research while fostering curiosity and sustained interest in science-related careers. The program offers a mutually beneficial model for students, faculty, and research teams. Through participation in AIRE, students gain meaningful exposure to active research projects, develop essential communication skills through interactions with research participants, families, research assistants, and faculty, and gain insight into a wide range of career pathways. These pathways include roles such as clinical research coordinators, research assistants, research nurses, graduate students, and combined MD/PhD (Medical Scientist Training Program, MSTP) trainees. In addition, AIRE students build a strong foundation in clinical, translational, and basic research, including principles of research safety, scientific rigor, and hands-on application of the scientific method. Program evaluation data from the past two years clearly demonstrate positive outcomes, underscoring AIRE's effectiveness in providing meaningful opportunities for students to explore research within a real-world healthcare setting. Importantly, these experiences equip students with the knowledge, skills, and confidence needed to pursue advanced training, strengthening their preparedness

and competitiveness as they apply to graduate programs, medical schools, and other institutions of higher learning.

These outcomes align with a robust body of literature demonstrating that undergraduate research participation enhances research self-efficacy, scientific identity, and persistence toward graduate and professional careers in the health sciences [11, 12, 17]. Many established undergraduate research programs, including NSF-funded Research Experiences for Undergraduates (REUs) and discipline-specific summer institutes, are structured as short-term, intensive experiences lasting approximately 8–10 weeks (<https://www.nsf.gov/crssprgm/reu/>). While these models have been shown to increase students' interest in research careers and technical skill development, their time-limited nature may constrain opportunities for deeper engagement, particularly for students with limited prior research exposure. AIRE was intentionally designed to address this gap through a year-round, multi-semester structure that emphasizes sustained participation and progressive skill development.

Compared with short-term summer programs, AIRE's extended duration allows students to move beyond introductory exposure toward meaningful integration within active research teams. The high return rate observed among AIRE participants (82.1% completing two or more semesters) suggests that sustained immersion promotes engagement, continuity, and perceived value. Prior studies have shown that longer and more immersive undergraduate research experiences are asso-

ciated with stronger gains in research confidence, independence, and clarity of career goals [11, 17]. By participating across multiple semesters, AIRE students are able to observe and contribute to multiple phases of the research process, reinforcing a more authentic understanding of team-based basic, clinical, and translational research.

AIRE also differs from many traditional undergraduate research models through its intentional integration of both clinical and basic science research tracks within a pediatric hospital environment. Previous work has demonstrated that clinical immersion experiences enhance professional communication skills, ethical awareness, and understanding of interdisciplinary collaboration [8, 12]. AIRE extends these benefits by embedding students in a real-world healthcare setting where research, interaction with research participants and families, and education are tightly integrated. Direct interaction with clinicians, research coordinators, nurses, laboratory staff, research participants, and families provides students with a holistic view of how scientific discovery informs clinical practice and how clinical observations generate research questions. This dual track structure, coupled with cross exposure between tracks, broadens students' awareness of health science career pathways beyond traditional laboratory roles.

Mentorship is a central component of AIRE and a key contributor to its success. Consistent with extensive evidence demonstrating that structured mentoring positively influences undergraduate persistence and pursuit of advanced training [9, 10, 19], AIRE incorporates layered mentorship involving faculty, research staff, and near-peer trainees. Monthly mentor meetings, career exploration discussions, and peer mentoring opportunities create a supportive mentoring ecosystem rather than a single mentor–mentee dyad. Strong student satisfaction with mentoring observed in program evaluations aligns with prior findings that frequent, intentional mentoring interactions are essential for maximizing the impact of undergraduate research experiences.

Finally, AIRE reflects best practices related to inclusivity and early exposure to research. Studies of course-based undergraduate research experiences and participatory research models highlight the importance of reducing barriers to entry and providing structured guidance to support students from diverse backgrounds [17, 18]. AIRE's flexible participation options, emphasis on early undergraduate involvement, and systematic incorporation of student feedback contribute to a learner-centered and inclusive model. The program's ongoing refinement, such as plans to increase mentor meeting frequency and formalize mentor–mentee expectations, demonstrates a commitment to continuous improvement consistent with recommendations from evaluations of successful undergraduate research programs.

Collectively, these findings suggest that AIRE not only aligns with evidence-based practices in undergraduate research training but also extends existing models by demonstrating the feasibility and benefits of an academic, pediatric hospital-based, immersive, year-round undergraduate research program.

Limitations of the Study

While the findings presented here are encouraging, there are limitations that should be considered when interpreting the results. First, the sample size is relatively small, with a total of 45 participants to date and survey responses obtained from a subset of program alumni. Although this is typical for a single-site pilot program and provides valuable preliminary insights, the modest cohort size may limit the statistical power and generalizability of the findings. Future expansion of the program and longitudinal tracking of additional cohorts will be important to confirm the robustness and reproducibility of these outcomes.

Second, the AIRE program was developed and implemented at a single academic pediatric medical center, which may limit the broader applicability of the results. The unique infrastructure, institutional resources, and strong integration of clinical and research environments at CCHMC likely contributed to the program's success. As such, outcomes observed in this setting may not be directly generalizable to institutions with fewer resources or different educational structures. Multi-institutional implementation and evaluation will be necessary to determine the scalability and adaptability of the AIRE model across diverse academic settings.

Third, there is potential for selection bias, as participation in AIRE requires students to apply and commit a significant amount of time (≥ 10 hours per week). This may preferentially attract highly motivated, academically strong students who are already inclined toward careers in science or medicine. Consequently, the observed positive outcomes, including high retention rates, strong satisfaction, and continued progression into health-related careers, may partially reflect pre-existing interest rather than the program's independent effect. Future studies incorporating comparison groups or broader recruitment strategies could help distinguish program-specific impact from baseline student motivation.

5. Conclusions

Despite these limitations, AIRE program demonstrates a promising and potentially generalizable framework for undergraduate research training. By fostering a collaborative, team science environment, the AIRE program cultivates scientific curiosity, professional identity formation, and skill development that are likely to positively impact the next generation of scientists and health care professionals. Through sustained immersion, interdisciplinary exposure, and structured mentorship, AIRE provides undergraduates with an authentic introduction to clinical, translational, and basic science research within a real-world pediatric hospital setting. Moreover, documenting the design, outcomes, and lessons learned from AIRE offers a replicable framework for institutions seeking to expand access to meaningful undergraduate research experiences. As the demand for a well-prepared biomedical and health science workforce continues to grow, programs such as

AIRE represent an effective and scalable approach to strengthening the pipeline of future researchers and clinician scientists.

Abbreviations

AIRE Asthma Immersive Research Experience

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Elisabet Johansson: Methodology, Project administration, Supervision, Writing – review & editing

Wan Chi Chang: Data curation, Formal Analysis, Visualization, Writing – review & editing

Melinda Butsch Kovacic: Validation, Writing – review & Editing

Gurjit Kaur Khurana Hershey: Conceptualization, Methodology, Supervision, Writing – review & editing

Latha Satish: Data curation, Formal Analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft

Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interests

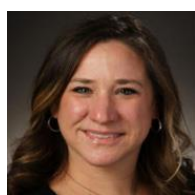
The authors declare no conflicts of interest.

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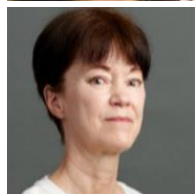
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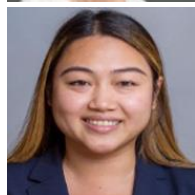
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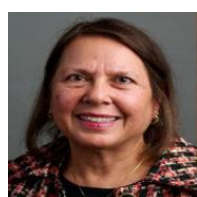


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