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Building a First- and Second-Year Undergraduate Research Program in Engineering, Science, and Mathematics

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Abstract

Mentored undergraduate research experiences offer a unique venue for STEM students to collaborate closely with faculty members while also developing problem-solving skills and a sense of connection to the broader engineering and science community. Early exposure to research experiences has been shown to increase student retention, self-efficacy, and persistence in STEM fields. However, many first- and second-year students remain unaware of these opportunities or are unsure how to get involved.

To address this challenge, we created a Research Fellows program at our small, STEM-focused undergraduate institution that provides a pathway for involving more first- and second-year students in research and helps set students up for success in their projects. The Research Fellows program spans a full academic year, starting with a 1-credit course in the fall term that introduces the process of research and aids in matching with a faculty member for a mentored research experience. Students start their research experience in the winter term while also taking a 1-credit course on research communication. They continue their research projects into the spring term and present their results at a poster session at the end of the academic year. The program also aims to foster a sense of community in student researchers through networking events, speakers, and peer mentorship opportunities.

In this paper, we will discuss the Research Fellows program structure, learning outcomes, and course development, with an emphasis on applicability for engineering programs and comparison to existing models for first-year research programs. We will also present assessment results from the initial two years of the program based on course evaluations, interviews with participants in the program, and faculty mentor surveys. Our student interviews were designed to explore whether the program helped reduce barriers to research at our institution, allowed students to develop research skills, and aided students in developing a sense of identity as a researcher. Faculty surveys focused on whether faculty mentors felt the students were adequately prepared for their research experience and actively engaging with their project, as well as their perceived value of the program for recruiting and retaining undergraduate researchers. Preliminary results from course evaluations, student interviews, and faculty surveys indicate that the program helped students gain confidence and foundational research skills, appreciate the value of structured mentorship, and develop a stronger sense of belonging to a research community.

The lessons learned from our Research Fellows program can be applied at other undergraduate institutions interested in incorporating mentored undergraduate research in engineering early in the college experience.

Introduction

The Rose Research Fellows (RRF) program was established in 2023 at Rose-Hulman Institute of Technology, a primarily undergraduate Science, Technology, Engineering and Mathematics (STEM)-focused institution, to help provide a structured pathway for students to become involved in undergraduate research. The RRF program is open to first- and second-year students and spans one academic year. It includes two 1-credit courses (fall and winter quarters) that introduce the process of research and aid in matching each student with a faculty member for a mentored research experience. Students conduct a faculty-mentored research project over two quarters (winter and spring quarters) and present their results at a poster session at the end of the academic year. Initial program development was motivated by a desire to provide equitable routes for early access to research opportunities on campus, especially among students who may be less familiar with the process or research or with norms for contacting faculty regarding independent projects.

Benefits of early undergraduate research experiences

Undergraduate research experiences (UREs) have been identified as a high-impact practice in undergraduate education, with studies indicating that, among other benefits, UREs can help students clarify their career goals [1], develop a feeling of identity as an engineer or scientist [2], and increase their resilience and ability to persist through failure [3]. While UREs are meaningful at any time, providing opportunities early can enhance many of these benefits and allow students an earlier understanding of research as a career path so they can consider alternatives or pursue more extended opportunities as desired [4]. Early involvement in undergraduate research is also correlated with increased first-year university satisfaction [5] and increased retention in STEM fields, especially for students from underserved populations [6], [7], [8].

While there are many benefits of early engagement with undergraduate research, it is still a challenge for students and universities. Students may be unaware that research opportunities are available for undergraduates or uncertain how to contact professors regarding research. Faculty may also be hesitant to hire first- and second-year undergraduates due to concerns about their preparation and the level of support that will be required [4].

Benchmarking: First- and second-year research programs in STEM

To guide development of the RRF program, a variety of models for early research experiences were explored. Benchmarking focused on multi-semester programs and apprentice-style undergraduate research rather than single semester, course-based undergraduate research experiences (CUREs) for first-year students. CUREs are a successful model for introducing large numbers of students to research, especially in settings like introductory biology courses. However, for the RRF program, one goal was to facilitate faculty-student interactions on individual or small-group projects beyond the standard classroom setting.

In benchmarking, several core models emerged for early research experiences. One model, implemented through programs such as the First-Year Innovation and Research Experience (FIRE) at the University of Maryland [9], [10] and the Freshman Research Initiative (FRI) at the University of Texas at Austin [11], assigns first-year students to research streams guided by a faculty member or team of faculty. The programs involve a combination of research-focused coursework and independent or team-based work on a research project. While these programs integrate some elements of a CURE, they extend over several semesters and are designed as a pathway to apprentice-style research. This type of program can be highly impactful and serves a large population of students but is also resource intensive (e.g., requiring dedicated program staff).

For individual departments or smaller universities, early research programs have been developed that can be administered by a single program director or undergraduate research program officer in collaboration with individual faculty. The Early Research Scholars Program (ERSP) is a model that has been implemented within computing departments across several different universities [12]. In this program, second-year computing students take a course introducing research methods and carry out faculty-mentored research in teams of 2-4 students. The program runs during the academic year, allowing students to complete off-campus internships if desired.

The University of Central Florida developed the Learning Environment and Academic Research Network (LEARN program), a living-learning community focused on allowing students to build relationships with faculty through undergraduate research experiences [8]. Students complete introductory coursework in research and a research apprenticeship while also engaging in social and mentorship activities within their learning community.

Many other first-year research experience programs have been introduced in recent years at a range of institutions, from large research universities to small primarily undergraduate institutions. Common themes among these early research programs include introductory coursework in research skills; assistance in student-mentor matching through project lists or research streams, opportunities for mentorship beyond research advisors, (e.g., from peer mentors or program staff); and structures to encourage extended engagement in research, like multi-semester programs, pathways to summer research, and undergraduate research symposia. These aspects were all considered in the development of the RRF program.

Program structure and goals

Program structure

The RRF program involves first and second-year students in undergraduate research through a structured framework including introductory courses, matching students with mentors, paid research experiences, and networking. Applications are reviewed in the spring for rising second-year students and the summer for incoming first-year students. The application process is competitive, as not all interested students can be accommodated in the program. Students submit written responses to the application questions, along with a transcript. Assessment of applications is based on a rubric that emphasizes evidence that students can balance the program requirements with their coursework. The program activities then extend over the following academic year with the schedule shown in Figure 1.

The structure of the RRF program builds community among undergraduate researchers and prepares them for authentic research experiences in the winter and spring quarters. The program coordinators teach the introductory course series, assist students with matching with a faculty mentor or an industry partner, and arrange peer mentorship groups. Students also have the opportunity to interact with alumni and external researchers through speaker events.

Faculty mentors involved with the program mentor individuals or small groups of students on research projects related to their interest area, using existing facilities. The RRF program also provides supplies funding and administrative support to allow faculty to focus on collaborating with students, rather than managing hiring and payroll.

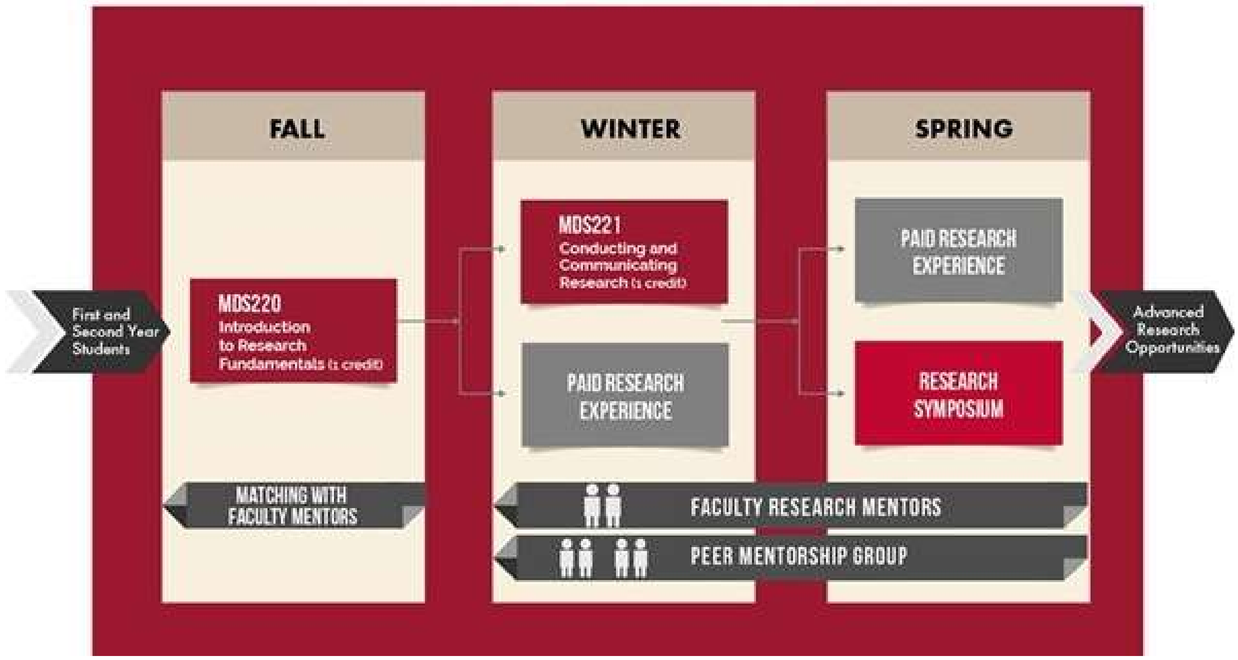

Figure 1: Rose Research Fellows program organization and timeline.

Introductory research courses
Two new, 1-credit courses were designed for students in the RRF program, Introduction to Research and Conducting and Communicating Research. The courses were designed to introduce the process of undergraduate research and aid in research skill development across all STEM majors. This course structure was selected to allow students flexibility in fitting the courses alongside program requirements in engineering and the sciences. These courses could count as elective credit but did not replace required introductory coursework with each major.

During the first course, Introduction to Research, students have not yet started their research project but are actively defining their interests and meeting with potential mentors. The course supports development of skills needed for starting a research project and aligning it with professional development goals. The course emphasizes how students can understand the context of their research and take ownership of a new project. Students complete the second course, Conducting and Communicating Research, concurrently with the start of their research project. This course focuses on research planning and communication skills. Key learning objectives for these courses are summarized in Table 1.

The activities used to support these learning objectives in both courses were adapted and modified from freely available resources including workshops integrating entrepreneurial mindset in research previously developed by one of the authors, which are available on Engineering Unleashed [13], and the Entering Research curriculum, which is available from Center for Improvement of Mentored Experiences in Research [14], [15].

Table 1: Key learning objectives for the RRF course sequence.

Introduction to Research (Fall)	Conducting and Communicating Research (Winter)
Describe the high-level process involved in conducting engineering or scientific research.	Set expectations and goals for your undergraduate research experience.
Describe the unmet need being addressed by an example area of research and the potential impact of the research.	Write a research abstract, integrating knowledge about the structure, audience, and goals for the abstract.
Conduct a basic literature search. Identify the sections of a research paper and extract key information from each section.	Prepare a basic experimental design within your field.
Describe appropriate documentation practices for research in your field.	Compare the advantages and disadvantages of different strategies for data visualization.
Discuss ethical practices in research and identify concerns specific to your field.	Describe the attributes of an effective research poster and create a template that can be used in the program's research symposium.
List your professional development goals and how those align with undergraduate research.	Develop an effective research presentation for your project.

Faculty-mentored research project

As part of the RRF program, students conduct research with a faculty mentor for 5 hours per week over two 10-week quarters (winter and spring). Student matching with faculty mentors occurs during the fall quarter and is scaffolded through the Introduction to Research course. Students receive a list of potential faculty mentors along with brief descriptions of their ongoing projects. As a course assignment, students are asked to assess their own research interests, make appointments to speak with at least two potential mentors, report on the meetings, and come to an agreement with one faculty mentor to start research in the winter quarter. Students may contact faculty members regarding the listed projects, or they may choose to propose their own project and then contact other faculty to find someone willing to mentor research in that area. The RRF program director collects the research matching assignments and confirms the faculty / student research matches before the end of the fall quarter. During the winter and spring quarters, students are expected to work on their research project for 5 hours per week and meet regularly with their faculty mentor. Students are paid for their research at an hourly rate equivalent to similar on-campus jobs. At the end of the spring quarter, students present posters on their work at the Spring Research Symposium, which is advertised to students, faculty, and staff across campus.

Peer mentorship

Interaction with multiple mentors can be valuable for undergraduate researchers [12], especially younger researchers who may not feel comfortable voicing concerns with their direct research supervisor. Near-peer mentorship groups can provide a welcome venue to discuss challenges in research and also next steps, such as applying for summer research programs. Initially, peer mentors were recruited among juniors and seniors with previous research experience, transitioning to a model where previous RRF participants serve as peer mentors. Students are organized into groups of 3-5 mentees with 1-2 mentors. Peer mentors receive an introductory mentorship training introducing case studies of research challenges adapted from *Entering Research* [15] and the Open questions, Affirmations, Reflections, and Summaries (OARS) model of communication [16]. Peer mentors are encouraged to schedule 1-2 group meetings per quarter and are asked to serve as a resource for individual questions.

Program assessment

There is extensive literature on assessment of undergraduate research programs, and several validated surveys have been developed to assess development of research skills, attitudes, and outcomes among undergraduate students [17], [18], [19], [20]. For the RRF program, we hoped to assess the unique benefits and challenges of a program targeted at novice researchers. We were especially interested in whether the program helped reduce barriers to research at our institution, allowed students to develop research skills, and aided students in developing a sense of identity as a researcher. Among faculty, we wanted to explore whether mentors felt the students were adequately prepared for their research experience and actively engaging with their project, as well as their perceived value of the program for recruiting and retaining undergraduate researchers.

Previous qualitative studies have been valuable in understanding the challenges and benefits of undergraduate research for faculty and students. In interviews conducted by Hunter *et al.*, both students and faculty identified benefits associated with integration of students into a "community of practice", where novice researchers become familiar with the norms of the scientific community through interaction with experienced researchers including faculty mentors and graduate students [2]. Faculty members identified these benefits as a direct part of "professional socialization" while students more commonly associated them broadly with skill and career development. Gardner *et al.* examined the integration of first-year students into a community of practice in scientific research after their first research experience. These students perceived barriers to interaction with faculty and relied heavily on the community of graduate students and peers for support [21], which could indicate an important role of informal mentors and peer communities like those in the RRF program. Other researchers have also investigated the role of undergraduate research in the formation of students' feelings of professional identity, such as engineering identity and identity as a researcher. Faber and Benson found that specific activities and skills reinforced students' perceptions of their identity as a researcher, including working on independent projects, presenting their work, talking about research with people outside their field, and receiving recognition from faculty mentors [22].

Given the value of this type of qualitative assessment in identifying strengths and areas for improvement in mentored research experiences, we chose to place an emphasis on qualitative data collection in our program assessment through student interviews and analysis of responses to open-ended questions on faculty surveys and student course evaluations. We developed the following research questions to inform design of the guide for our student interviews:

- Does the RRF program help students develop research skills and advance their career goals?
- Do students develop a greater feeling of identity as a researcher and feel part of a research community?
- Do students perceive that the program helps in reducing barriers to research?

Development of interview questions related to students' feelings of identity as a researcher were informed by findings reported by previous studies of identity development among undergraduate researchers and engineering students [2], [21], [22], [23].

Methods

Data sources

Qualitative data were collected from three primary sources: (1) open-ended items on student course evaluations, (2) open-ended interviews with student participants, and (3) open-ended items on faculty-mentor surveys. Student instruments focused on perceived barriers to research involvement, development of research skills, and research identity. Faculty instruments focused on student preparedness, engagement, and the perceived value of the program for recruiting and retaining UG researchers.

Analytic approach

The authors analyzed qualitative data using reflexive thematic analysis as described by Braun and Clarke [24]. The goal of the analysis was to identify patterned meanings related to the program's impact on students' research skills, confidence, and sense of belonging in a research community, as well as faculty perceptions of student preparedness and program value.

Familiarization and initial coding

All open-ended survey responses and interview transcripts were read multiple times for familiarization. The authors then generated initial codes utilizing a hybrid inductive-deductive strategy. Deductive codes were informed by the program's stated learning outcomes (e.g., research skills, research identity, sense of belonging, mentorship), while inductive codes were developed from recurring ideas emerging from the collected data (e.g., *"time constraints"*, *"imposter feelings"*, *"structured expectations"*, and *"peer support"*). Coding was conducted at the semantic level (participants' explicit statements) with attention to latent meanings when relevant. In other words, data were coded based on what participants directly stated, while also identifying broader underlying patterns that emerged across interviews and surveys.

Theme development and review

Codes were iteratively grouped into candidate themes representing broader patterns across the dataset, such as *"gaining confidence as a researcher," "reducing barriers to getting started,"* and *"mentorship as a bridge into the research community."* The authors reviewed and refined themes by checking them against the coded data extracts and the full data set to ensure internal coherence and clear distinctions between themes.

Defining and naming themes

Each theme was then defined in terms of its central organizing concept and its relationship with the research questions. Representative quotes from students and faculty were selected to illustrate each theme.

Quantitative analysis of survey items

Likert-scale ratings from course evaluation items were analyzed using descriptive statistics (means, standard deviations, and response distributions). Where applicable, the authors compared responses across program years (2023-24 and 2024-25) to examine consistency in perceived benefits. These quantitative results are used to complement and contextualize the qualitative themes.

Institutional review and confidentiality measures

This study was approved as exempt human subjects research by the Institutional Review Board (IRB) at Rose-Hulman Institute of Technology. All participants were informed that their participation was voluntary and that their responses would remain confidential. The student interviews were conducted by two professional staff members, one of whom is a co-author. These staff members were not involved in the administration, instruction, or assessment of the RRF Program, which minimized potential power dynamics or perceived pressure to participate.

A total of 33 students participated in the RRF program during the 2023–24 and 2024–25 academic years. 30 students completed course evaluations after completing MDS220 and/or MDS221. From the two cohorts, six Research Fellows volunteered for interviews at the conclusion of their program. Interviews were transcribed, and all identifiable information was removed during the transcription process.

The anonymized transcripts were then summarized to capture key ideas, recurring sentiments, and representative statements. The authors reviewed these summaries to ensure accuracy and completeness. The resulting comments and reflections were incorporated into the thematic analysis and evaluated alongside faculty mentor surveys, and open-ended course evaluation data.

Results

Analysis of student interviews, faculty mentor surveys, and open-ended student course evaluations revealed six interrelated themes that describe how students experienced the RRF program and how faculty perceived its impact. These themes highlight the program's role in fostering research identity and confidence, the value of structured scaffolding and community, and the logistical and structural challenges that shape early undergraduate engagement with research. Figure 2 provides a visual representation of emergent themes from the thematic analysis of the RRF program.

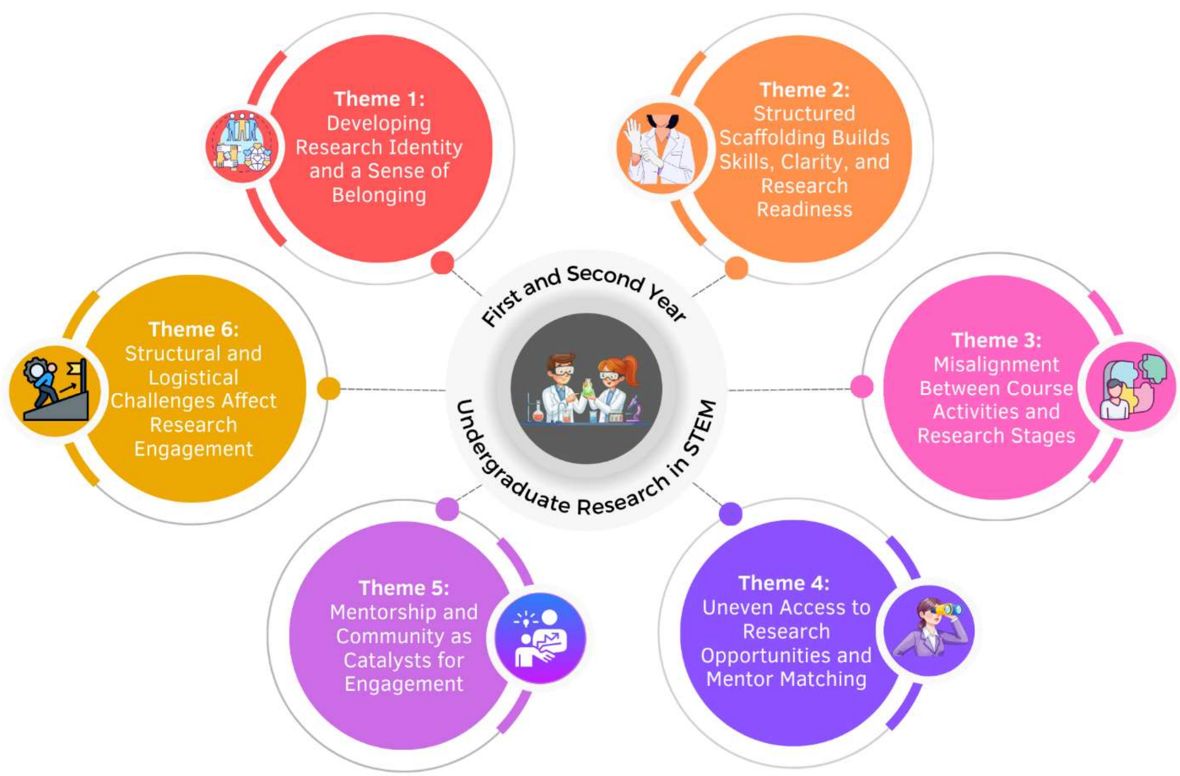

Figure 2: Emergent themes from thematic analysis of the RRF program

Theme 1: Developing Research Identity and a Sense of Belonging
Across both cohorts, students consistently reported that participation in the RRF program helped them *"feel like a researcher"* and gain confidence in their ability to contribute meaningfully to research. Interview summaries noted that students began to identify as members of the research community, with many participants referencing increased confidence, independence, and self-efficacy. One student described the opportunity to conduct research as a first-year student as *"incredible,"* expressing excitement that *"this is so cool!"* and emphasizing that early research engagement increased their motivation.

Students also emphasized the importance of belonging, frequently highlighting the sense of community fostered within the cohort. Interview participants "greatly appreciated the community," describing it as a motivating and reassuring environment where they could share challenges and successes. For some, this was their first exposure to a research culture, and feeling welcomed was described as critical in reducing intimidation and uncertainty; common barriers for first- and second-year students in colleges.

These findings align with research on scientific identity formation and suggest that early, structured research engagement can play a significant role in fostering a sense of belonging within STEM fields.

Theme 2: Structured Scaffolding Builds Skills, Clarity, and Research Readiness
Both students and faculty emphasized the value of the program's structured support. The fall and winter courses, combined with clear deliverables such as the required poster presentation, provided a scaffolded introduction to research skills. Faculty mentors noted that the poster requirement *"helped maintain milestones,"* supported progress, and gave students a tangible goal to work toward.

Students reported that assignments and discussions enhanced their understanding of research practices, literature review methods, and scientific communication. They identified specific modules such as reading scientific papers, annotated bibliographies, and research planning as especially helpful in preparing them for their projects. As one student reflected, the structured schedule *"provided me with a fixed structure… otherwise I would have put everything to the last minute."*

This structured approach reflects cognitive apprenticeship frameworks and appears particularly effective for first-year students who may lack experience in open-ended or ambiguous research environments.

Theme 3: Misalignment Between Course Activities and Research Stages
Despite the benefits of the scaffolded curriculum, many students expressed frustration with the timing of certain assignments relative to their actual progress in their research projects. Several students noted that they were required to complete assignments *"before I had actually done that part of my research,"* leading to rushed or speculative responses that did not accurately reflect their work. Winter quarter students especially felt that the course occurred *"before my research had really gotten started,"* making certain communication-related assignments difficult to complete.

Faculty echoed these concerns indirectly, describing mismatches between their expectations of student readiness and students' actual skill sets or stages of progress. One mentor reported that a student struggled with background content that had been assumed, while another described the need for earlier introduction to certain research skills.

Together, these findings suggest that although the curriculum effectively teaches core research skills, its impact would be strengthened by better synchronizing course content with students' research timelines.

Theme 4: Uneven Access to Research Opportunities and Mentor Matching
A major challenge identified in both student interviews and course evaluations was the difficulty of finding a research mentor or identifying appropriate projects, particularly for students in disciplines with limited research availability. Students reported feeling uncertain about which faculty were engaged in research and where opportunities existed, with some describing the search for a mentor as *"challenging"* or *"confusing."*

Faculty similarly expressed a desire for improved communication related to student backgrounds and research preparation. One mentor noted that access to a student's application or prior experiences *"would have been useful"* in setting expectations and calibrating project assignments. Mentors also noted that students' research interests were sometimes misaligned with available projects.

These findings highlight a structural barrier to equitable participation in early research experiences. Improving transparency around faculty research projects and implementing earlier mentor matching processes may help reduce these access disparities.

Theme 5: Mentorship and Community as Catalysts for Engagement
Mentorship, both faculty and peer, played a central role in shaping students' research experiences. Faculty mentors described their students as *"proactive," "committed,"* and *"highly engaged,"* attributing these qualities to a combination of student motivation and program structure. Students consistently praised their instructors for being *"helpful," "supportive,"* and *"very good at giving advice."*

Peer interactions also contributed significantly to engagement. Students valued the cohort model, group discussions, and shared experiences, noting that these elements helped sustain motivation and decrease feelings of isolation. One student remarked that the class *"keeps you on track with ongoing research,"* while another emphasized the value of learning from peers' projects and approaches.

These findings align with social learning and apprenticeship literature, suggesting that structured mentorship and peer community are essential components for supporting early researchers.

Theme 6: Structural and Logistical Challenges Affect Research Engagement
Finally, students and faculty identified several logistical challenges that hindered research progress. Scheduling conflicts between coursework, research hours, and mentor availability were frequently cited. Faculty noted that they struggled to find consistent meeting times with students, while students described feeling overwhelmed by competing demands.

Several students commented that the workload of the fall course felt disproportionately heavy for a 1-credit class, particularly during busy weeks or when other courses required substantial effort. Others expressed difficulty balancing research with academic responsibilities, leading to uneven engagement throughout the year.

Faculty also identified cases where mentoring was complicated by factors such as uncommunicated learning needs or mismatched expectations about student background knowledge.

Collectively, these challenges indicate areas where structural adjustments such as streamlined assignments, enhanced communication, and coordinated scheduling could further strengthen the program.

Quantitative course evaluation results
Closed-ended items from course evaluations in the fall and winter RRF courses were analyzed using descriptive statistics to contextualize the qualitative findings. Across both academic years, 2023-24 and 2024-25, students reported generally positive perceptions of learning, instructional support, and overall course quality.

For the *MDS220: Intro to Research Fundamentals* course, mean ratings for overall course quality ranged from 3.58 to 4.11 out of 5, with median ratings consistently at 4 (Very Good). Ratings of instructor preparedness and availability were high across cohorts, with mean values ranging from 4.50 to 4.79.

For the *MDS221: Conducting and Communicating Research* course, mean overall course ratings ranged from 4.08 to 4.14, with most students selecting *Excellent* or *Very Good*. Items related to instructional effectiveness and instructor availability consistently received mean ratings above 4.3.

Perceptions of workload were more mixed. While many students rated the workload as *"about the same"* or *"lighter"* than other one-credit courses, a subset of students (7 – 33%) rated the workload as *"heavier,"* particularly in the fall course. Response rates across courses ranged from 78% to 100%.

Discussion

The purpose of the RRF program was to create an accessible, structured pathway for first- and second-year students to participate in authentic research experiences while developing the skills and confidence necessary to contribute meaningfully to faculty-mentored projects. Findings from student interviews, faculty mentor surveys, and course evaluations demonstrate that the program is largely successful in supporting early undergraduate researchers. However, the results also reveal structural and logistical challenges that should be addressed to strengthen program coherence and impact. Below, we situate these findings within relevant literature and discuss implications for future iterations of the program.

Early Research Engagement Promotes Research Identity, Belonging, and Confidence
A central outcome of the program was the development of students' confidence and research identity. Students reported increased self-efficacy, a stronger sense of belonging in the research community, and enthusiasm about participating in authentic research so early in their undergraduate careers. These outcomes align with prior work showing that early research experiences can be transformative for students [25], shaping academic trajectories [5], [26], increasing retention in STEM [27], [28], and improving persistence in research careers [25], [29].

The RRF program appears to provide the structural support necessary for students to engage meaningfully with research even before they have developed substantial disciplinary expertise. Vygotskian perspectives on learning and communities of practice [30] help explain why the cohort model and mentorship were especially impactful: students were not only learning about research but also learning to be researchers alongside peers and mentors. These findings reinforce the importance of fostering community early in students' research journeys to reduce intimidation and build confidence.

Scaffolding and Structured Coursework Effectively Prepare Students for Research

The structured curriculum in the fall and winter courses played a significant role in preparing students to undertake research. Students described learning foundational skills such as reading scientific papers, conducting literature reviews, and communicating research for different audiences. Faculty emphasized how the poster requirement supported milestone-setting and ongoing engagement.

This scaffolding aligns with cognitive apprenticeship models [31], [32], which emphasize structured guidance, modeling, and gradually increasing independence. By providing clear expectations and tangible deliverables, the program reduces ambiguity and increases students' readiness to contribute to research projects.

These findings affirm the importance of maintaining structured coursework as an anchor for early research programs. At the same time, the data indicates that the timing and alignment of these assignments with students' actual research progress warrant reconsideration.

Misalignment of Course Content and Research Timelines Limits Learning Transfer

A notable challenge across students and mentor responses was the misalignment between course activities and the stages of students' research projects. Students reported difficulty completing communication-focused assignments before they had conducted sufficient research, while faculty described mismatches in expected and actual student preparation.

This disconnect echoes findings in the literature that emphasize the importance of synchronizing skill development with authentic practice in undergraduate research [33], [34]. When coursework does not align with research activities, students may struggle to apply newly learned skills and experience unnecessary frustration. The feedback suggests that shifting certain assignments later in the year, revising the sequence of the fall and winter courses, or facilitating earlier mentor pairing could improve coherence and maximize learning transfer.

Opportunity Structures and Research Visibility Influence Access and Equity

The difficulty some students experienced in finding mentors or identifying research opportunities highlights a structural barrier that is well-documented in the literature on undergraduate research participation [35], [36]. Access to research often depends on informal networks, awareness of faculty research programs, and disciplinary cultures–components of the "hidden curriculum" that disadvantages students without prior exposure.

The program's intention to democratize access to research is clear, yet it appears that departmental constraints and varying levels of faculty engagement may create inequities. Increasing transparency around faculty research interests, offering structured matching events, or implementing a centralized project database could help mitigate these barriers. Faculty requests for more information about student backgrounds also point to a need for improved communication and alignment between program administrators and mentors.

Mentorship and Community Remain Central to Student Engagement

Students and faculty consistently identified mentorship and community as critical contributors to successful research experiences. Strong faculty mentorship promoted students' confidence and independence, while peer interactions facilitated reflection, motivation, and collaborative learning. These findings align with decades of research demonstrating that mentorship is one of the strongest predictors of undergraduate research success [25], [26] and that belonging to a community of learners enhances persistence in STEM pathways [25], [29].

The program's cohort model appears to be a key strength. Continued investment in community-building experiences such as structured peer mentoring, research roundtables, or interdisciplinary networking events may further amplify these benefits.

Structural and Logistical Constraints Affect Research Engagement and Satisfaction

Finally, students and faculty highlighted several logistical challenges that impeded research productivity, including scheduling conflicts, workload imbalances, and communication gaps. These challenges are not unique to this program; early undergraduate researchers often struggle to balance coursework, extracurricular commitments, and research responsibilities [36], [37], [38]. However, careful program design can help mitigate these pressures.

Reducing the volume of weekly assignments, integrating more in-class work time, coordinating expectations across courses, and improving mentor–instructor communication may enhance students' capacity to engage deeply with research. Addressing these structural issues is particularly important given the heavy cognitive and emotional load often experienced by first-year students navigating unfamiliar academic expectations.

Quantitative Findings in Relation to Qualitative Themes

The quantitative course evaluation results provided additional support for the qualitative themes identified in this study. High ratings related to instructional quality and instructor availability are consistent with students' descriptions of structured scaffolding and supportive mentorship. At the same time, mixed workload ratings align with qualitative reports of timing misalignment and challenges balancing coursework with research responsibilities.

Taken together, these findings suggest that while the program's structure and mentorship are perceived positively, refinements to workload calibration and alignment between coursework and research activities may further enhance the student experience.

Implications for Program Enhancement

The findings suggest several actionable recommendations:

1. Improve alignment between coursework and research progress
    - Shift communication-focused assignments later in the year
    - Facilitate earlier faculty–student matching
    - Provide flexible assignment options depending on project stage

2. Increase transparency and access to research opportunities
    - Create a centralized database of faculty research projects
    - Host matching events or "research open houses"

   - Provide faculty with student background information earlier

3. Strengthen mentorship and community-building mechanisms
   - Expand peer mentoring models
   - Introduce regular check-ins involving students, mentors, and course instructors

4. Optimize workload and scheduling
   - Adjust the quantity and pacing of assignments in the 1-credit courses
   - Build in time for in-class research work
   - Coordinate expectations with mentors to avoid overload

Collectively, these changes may better support the program's goals of improving student preparedness, confidence, and retention in STEM research pathways.

Overall, the RRF program demonstrates strong potential for expanding early undergraduate participation in research and fostering research identity, self-efficacy, and a sense of belonging among first- and second-year students. By addressing structural and logistical challenges, particularly around mentor matching, assignment timing, and communication, the program can further enhance its effectiveness and serve as a model for other institutions seeking to broaden access to high-impact research experiences.

Conclusions and Future Work

The RRF program was designed to broaden access to undergraduate research by providing first- and second-year students with intentional scaffolding, structured mentorship, and early immersion in authentic research environments. Across two years of implementation, student interviews, faculty mentor surveys, and course evaluations demonstrate that the program is succeeding in its core aims. Students reported increased confidence, stronger research identity, and a greater sense of belonging within the research community– outcomes that are well established as central drivers of persistence and success in STEM pathways. Faculty mentors affirmed that structured deliverables and consistent program support helped students stay engaged and make measurable progress on their projects.

At the same time, the findings highlight important areas for refinement. Students and faculty frequently noted misalignment between course assignments and the timing of research activities, challenges in identifying mentors or suitable projects, and logistical barriers related to scheduling, workload, and communication. Addressing these structural issues through earlier mentor matching, increased visibility of faculty research, coordinated workload expectations, and improved synchronization between coursework and research stages may strengthen program coherence and enhance the learning experience for future participants.

With the recent implementation of the program, it was not possible to collect data on the longer-term impact of the program on students and faculty. However, future assessments could include analysis of the impact of RRF participation on student outcomes such as graduation rates and continuation into graduate programs or research-oriented careers. For faculty, metrics on retention of the student researchers within a laboratory and their output of publications or presentations over the course of their research engagement could help provide motivation to serve as a mentor.

By integrating structured learning, mentorship, and community-building with authentic research practice, the RRF program offers a promising model for supporting early undergraduate researchers in STEM. The lessons learned from this initial implementation provide valuable insights for institutions seeking to expand access to high-impact research experiences, particularly for students who may not otherwise view themselves as future contributors to scientific or engineering inquiry. Continued iteration, guided by student and faculty feedback, will help ensure that the program remains responsive, equitable, and effective as it grows.

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References

[1] A. L. Zydney, J. S. Bennett, A. Shahid, and K. W. Bauer, "Impact of Undergraduate Research Experience in Engineering," *Journal of Engineering Education*, vol. 91, no. 2, pp. 151–157, 2002, doi: 10.1002/j.2168-9830.2002.tb00687.x.

[2] A.-B. Hunter, S. L. Laursen, and E. Seymour, "Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development," *Science Education*, vol. 91, no. 1, pp. 36–74, 2007, doi: 10.1002/sce.20173.

[3] D. Lopatto, "Survey of Undergraduate Research Experiences (SURE): First Findings," *CBE*, vol. 3, no. 4, pp. 270–277, Dec. 2004, doi: 10.1187/cbe.04-07-0045.

[4] D. Buffalari *et al.*, "Integrating Research into the Undergraduate Curriculum: 1. Early Research Experiences and Training," *J Undergrad Neurosci Educ*, vol. 19, no. 1, pp. A52–A63, Dec. 2020.

[5] N. A. Bowman and J. M. Holmes, "Getting off to a good start? First-year undergraduate research experiences and student outcomes," *High Educ*, vol. 76, no. 1, pp. 17–33, Jul. 2018, doi: 10.1007/s10734-017-0191-4.

[6] M. T. Jones, A. E. L. Barlow, and M. Villarejo, "Importance of Undergraduate Research for Minority Persistence and Achievement in Biology," *The Journal of Higher Education*, Jan. 2010, Accessed: Jan. 08, 2026. [Online]. Available: https://www.tandfonline.com/doi/abs/10.1080/00221546.2010.11778971

[7] B. A. Nagda, S. R. Gregerman, J. Jonides, W. von Hippel, and J. S. Lerner, "Undergraduate Student-Faculty Research Partnerships Affect Studen Retention," *The Review of Higher Education*, vol. 22, no. 1, pp. 55–72, 1998.

[8] K. R. Schneider, A. Bickel, and A. Morrison-Shetlar, "Planning and Implementing a Comprehensive Student-Centered Research Program for First-Year STEM Undergraduates," *Journal of College Science Teaching*, vol. 44, no. 3, pp. 37–43, Jan. 2015, doi: 10.2505/4/jcst15_044_03_37.

[9] M. Fazelpour, B. T. Landon, J. W. Herrmann, and P. Killion, "Designing Innovations Research Stream – A Design Research Program for First-Year Students," presented at the 2023 ASEE Annual Conference & Exposition, Jun. 2023. Accessed: Dec. 12, 2025. [Online]. Available: https://peer.asee.org/designing-innovations-research-stream-a-design-research-program-for-first-year-students

[10] P. Killion and I. Page, “CURQ Vignette: University of Maryland’s First-Year Innovation and Research Experience (FIRE) Encourages Student Participation in Policy-Based Research,” *CUR Quarterly*, vol. 36, no. 3, Mar. 2016, doi: 10.18833/curq/36/3/9.
[11] G. Clark, S. Rodenbusch, and S. Roux, “Teaching Cell Signaling Through Research: The Freshman Research Initiative at The University of Texas at Austin,” *The FASEB Journal*, vol. 31, no. S1, p. 587.10-587.10, 2017, doi: 10.1096/fasebj.31.1_supplement.587.10.
[12] C. Alvarado, J. Hummel, D. Mirza, R. Revelo, and L. Yan, “Scaling and Adapting a Program for Early Undergraduate Research in Computing,” in *Proceedings of the 53rd ACM Technical Symposium on Computer Science Education V. 1*, in SIGCSE 2022. New York, NY, USA: Association for Computing Machinery, Feb. 2022, pp. 50–56. doi: 10.1145/3478431.3499336.
[13] “EM + Research Card Collection - Engineering Unleashed.” Accessed: Jan. 08, 2026. [Online]. Available: https://engineeringunleashed.com/card/5127
[14] “CIMER – Center for the Improvement of Mentored Experience in Research.” Accessed: Jan. 08, 2026. [Online]. Available: https://cimerproject.org/
[15] N. Balster, C. Pfund, R. Rediske, and J. Branchaw, “Entering research: a course that creates community and structure for beginning undergraduate researchers in the STEM disciplines,” *CBE—Life Sciences Education*, vol. 9, no. 2, pp. 108–118, 2010.
[16] M. Kwasny and C. Stiles-Shields, “Mentoring Using Motivational Interviewing: One Path to Becoming a Quality Mentor,” *AMSTAT News*, Sep. 01, 2016. Accessed: Jan. 08, 2026. [Online]. Available: https://magazine.amstat.org/blog/2016/09/01/mimentoring/
[17] T. J. Weston and S. L. Laursen, “The Undergraduate Research Student Self-Assessment (URSSA): Validation for Use in Program Evaluation,” *LSE*, vol. 14, no. 3, p. ar33, Sep. 2015, doi: 10.1187/cbe.14-11-0206.
[18] A. R. Butz and J. L. Branchaw, “Entering Research Learning Assessment (ERLA): Validity Evidence for an Instrument to Measure Undergraduate and Graduate Research Trainee Development,” *LSE*, vol. 19, no. 2, p. ar18, Jun. 2020, doi: 10.1187/cbe.19-07-0146.
[19] J. Willison, K. O’Regan, and S. K. Kuhn, “RSD7: Researcher Skill Development Framework (US English Edition),” 2018.
[20] J. L. Branchaw, A. R. Butz, and J. C. Ayoob, “The comprehensive researcher development framework (CRDF): Core learning outcomes for research training,” *PLOS ONE*, vol. 20, no. 9, p. e0332587, Sep. 2025, doi: 10.1371/journal.pone.0332587.
[21] G. E. Gardner, J. H. Forrester, P. S. Jeffrey, M. Ferzli, and D. Shea, “Authentic Science Research Opportunities: How Do Undergraduate Students Begin Integration Into a Science Community of Practice?,” *Journal of College Science Teaching*, vol. 44, no. 4, pp. 61–65, 2015.
[22] C. J. Faber and L. Benson, “Undergraduate students’ recognition and development as researchers,” in *2015 ASEE Annual Conference & Exposition*, 2015, p. 26.1617. 1-26.1617. 10.
[23] C. J. Faber *et al.*, “Undergraduate engineering students’ perceptions of research and researchers,” *Journal of Engineering Education*, vol. 109, no. 4, pp. 780–800, 2020, doi: 10.1002/jee.20359.
[24] V. Braun, V. Clarke, N. Hayfield, L. Davey, and E. Jenkinson, “Doing Reflexive Thematic Analysis,” in *Supporting Research in Counselling and Psychotherapy : Qualitative, Quantitative, and Mixed Methods Research*, S. Bager-Charleson and A. McBeath, Eds.,

Cham: Springer International Publishing, 2022, pp. 19–38. doi: 10.1007/978-3-031-13942-0_2.
[25] A. E. Weinberg, C. D. Trott, and L. B. Sample McMeeking, "Who produces knowledge? Transforming undergraduate students' views of science through participatory action research," *Science Education*, vol. 102, no. 6, pp. 1155–1175, 2018.
[26] K. R. Schneider, U. Nair, R. Straney, P. Lancey, and M. Tripp, "First-Year STEM Research Program Facilitates Long-Term Academic Success," *Journal of College Science Teaching*, vol. 50, no. 4, pp. 11–16, Mar. 2021, doi: 10.1080/0047231X.2021.12290513.
[27] M. Estrada, P. R. Hernandez, and P. W. Schultz, "A Longitudinal Study of How Quality Mentorship and Research Experience Integrate Underrepresented Minorities into STEM Careers," *LSE*, vol. 17, no. 1, p. ar9, Mar. 2018, doi: 10.1187/cbe.17-04-0066.
[28] M. Khasawneh, J. Dmello, and Y. Franco, "Campus Undergraduate Research Awareness and its Effect on Retention and Interest of STEM Majors," *IIE Annual Conference. Proceedings. Institute of Industrial and Systems Engineers (IISE)*, May 2021, Accessed: Jan. 07, 2026. [Online]. Available: https://par.nsf.gov/biblio/10314464-campus-undergraduate-research-awareness-its-effect-retention-interest-stem-majors
[29] P. R. Hernandez, A. Woodcock, M. Estrada, and P. W. Schultz, "Undergraduate Research Experiences Broaden Diversity in the Scientific Workforce," *BioScience*, vol. 68, no. 3, pp. 204–211, Mar. 2018, doi: 10.1093/biosci/bix163.
[30] J. Lave, *Situated learning: Legitimate peripheral participation*. Cambridge university press, 1991.
[31] A. Shah and A. G. Soosai Raj, "A review of cognitive apprenticeship methods in computing education research," presented at the Proceedings of the 55th ACM Technical Symposium on Computer Science Education V. 1, 2024, pp. 1202–1208.
[32] N. M. H. Hassan, "Using an Online Collaborative Learning Program Based on the Cognitive Apprenticeship Model for Developing Student Teachers' EFL Argumentative Writing and Critical Thinking Skills," *Sohag University International Journal of Educational Research*, vol. 10, no. 10, pp. 147–184, 2024.
[33] L. C. Auchincloss *et al.*, "Assessment of Course-Based Undergraduate Research Experiences: A Meeting Report," *LSE*, vol. 13, no. 1, pp. 29–40, Mar. 2014, doi: 10.1187/cbe.14-01-0004.
[34] A. R. Burmeister, K. Dickinson, and M. J. Graham, "Bridging trade-offs between traditional and course-based undergraduate research experiences by building student communication skills, identity, and interest," *Journal of microbiology & biology education*, vol. 22, no. 2, pp. 10–1128, 2021.
[35] Y. A. Adebisi, "Undergraduate students' involvement in research: Values, benefits, barriers and recommendations," *Annals of medicine and surgery*, vol. 81, p. 104384, 2022.
[36] S. Pierszalowski, J. Bouwma-Gearhart, and L. Marlow, "A systematic review of barriers to accessing undergraduate research for STEM students: problematizing under-researched factors for students of color," *Social Sciences*, vol. 10, no. 9, p. 328, 2021.
[37] A. Brew and L. Mantai, "Academics' perceptions of the challenges and barriers to implementing research-based experiences for undergraduates," *Teaching in Higher Education*, vol. 22, no. 5, pp. 551–568, 2017.
[38] J. R. Nolan, K. S. McConville, V. Addona, N. L. Tintle, and D. K. Pearl, "Mentoring undergraduate research in statistics: Reaping the benefits and overcoming the barriers," *Journal of Statistics Education*, vol. 28, no. 2, pp. 140–153, 2020.