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From Classroom Curiosity to Research Confidence: A Scaffolded Inquiry-Based Learning Framework to Engage Undergraduates in the Research Process

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INTRODUCTION

Undergraduate engagement in research is a vital component of developing critical thinking, problem-solving, and lifelong learning skills; yet many students encounter research only in upper-level courses or through selective opportunities, leaving early undergraduates uncertain on how to both conduct and contribute through research. This paper presents an educational framework for introducing undergraduate students to the research process through the intentional integration of inquiry-based learning (IBL) strategies in faculty-led research projects. The paper also highlights the feedback from the students who underwent the initial iterations of this effort.

The IBL offers a powerful framework for guiding students from passive learning toward active engagement in the research process. This paper aims to present an application of IBL strategies in encouraging undergraduate students to get involved in scholarly research. At Bowling Green State University (BGSU) School of Aviation (undergraduate programs), the authors (faculty members) attempt to introduce students to the practice of research by briefly discussing their past and on-going scholarly work during the initial introductory lectures of their courses. Consequently, this exposure sparks curiosity in some of the students, who eventually reach out to the faculty – taking initiative and first steps in research and opening pathways for deeper exploration. This work outlines a scaffolded, faculty-mentored, inquiry-based approach to intentionally nurture and guide this transition – from initial classroom curiosity about faculty research to conducting independent small-scale undergraduate research projects. Some of these students apply for and secure BGSU internal funding to conduct semester-long research projects. Utilizing multiple inquiry-based strategies, students typically progress from formulating questions and conducting literature reviews to developing internal grant proposals and completing the full research cycle at their own pace. Some students develop skills that enable them to be recruited onto externally funded research projects, while others extend their semester-long projects into Honors theses, manuscripts for publication, or pursue additional ideas through internal funding.

This paper presents our IBL-based mentoring framework, describes its implementation across course and research settings, and summarizes preliminary student insights and lessons learned. The paper also includes a qualitative analysis of student reflections and end-of-project evaluations to capture perceived growth in their skills, motivation, and understanding of the research process. Students typically give feedback about their research journey with us; preliminary feedback indicates that, although the process may be perceived as challenging and at times ambiguous, students develop increased confidence, enhanced research literacy, and a stronger sense of belonging within the academic research community. Therefore, this approach illustrates how intentional, inquiry-driven mentorship can effectively bridge the gap between traditional classroom instruction and authentic research engagement. The overall process also suggests that both aspects – faculty actively attempting to spark research curiosity in students, and students taking the first steps to reach out to faculty – are critical for engaging students early in research, building a strong student research pipeline, and developing a durable culture of undergraduate research in which students do not merely learn about research, but begin to see themselves as researchers.

INQUIRY-BASED LEARNING (IBL) FRAMEWORK

What is IBL: IBL can be defined as an educational approach in which students actively learn by asking meaningful questions as they continuously perform analytical and experimental activities [1]. In the process, students acquire knowledge of a particular subject as they are both encouraged and guided to create questions which will lead them to investigate the topic at hand [2][3]. IBL covers a range of teaching approaches, all of which are designed to motivate the learners to ultimately construct new understanding of the materials as they create meaningful questions [4]. Spronken-Smith et al [4] also noted that IBL can be categorized based on the scale, mode, and frame of the inquiry process. Based on the work of Staver and Bay [5], the three established modes of inquiry are structured inquiry, guided inquiry, and open inquiry. In the open inquiry, students are left to go through the inquiry cycle in which they formulate the questions themselves, engage with the topic materials and learning activities, communicate results, and evaluate the research [4].

How have others used it: While the IBL framework was primarily designed to facilitate learning for the students, the framework has been applied in other various areas including research. Even in the teaching area, IBL has been used in variety of contexts such as educational technology [6][7][8] and science education [9] to name a few. As means to encourage the practice of IBL among students, Seol et al. [2] developed the Stanford Mobile Inquiry-based Learning Environment (SMILE) tool in which students utilized mobile phones to create meaningful questions which were then solved and rated by their peers. In a different context, Harris and Tweed [10] concluded that while IBL approach can be effectively incorporated in research activities among students, to facilitate both research and teaching, the instructors have to ensure sufficient resources. Spronken-Smith and Walker [11] concluded in their study that instructors who aim to strengthen the teaching and disciplinary research, open, discovery-oriented IBL modes should be utilized. In a similar setting, Rodríguez et al. [12] conducted a study to determine effectiveness of interpersonal IBL course in which students in human biology major undertook as part of developing their creative and research skills. Their study showed that IBL open mode approach helped the students to grow these skills [12]. It should also be noted that IBL approach has been shown to help students develop research skills at even at earliest stages of learning. The findings of Chu et al. [13] demonstrated how IBL can be implemented to younger generation as early as 4th grade; their findings strengthened the conclusion of how students' research skills were enhanced upon the introduction of IBL method in their learning process. In a chemical education context, Adal et al. [14] noted that integration of project-based learning and inquiry-based learning concepts in a traditional lab course showed significant improvement in several measured dimensions including hypothesis formulation, experiments implementation, data analysis, and report writing. Overall, IBL framework can be adopted in various academic contexts to foster active learning and prepare students for both research and career roles.

Advantages and Disadvantages: Over time, although the IBL approach has shown to help students excel in their learning process compared to those who are not exposed to the approach [9]. A study conducted by Cho et al. [15] showed how the students' perception toward IBL was more positive as they noted that their participation during the course module materials' offering increased. The students also noted that the IBL approach encouraged them to participate and engage with both their peers and instructors [15]. In the study by Berg, Bergendahl, and Lundberg [16], they noted that students who underwent through an open mode of inquiry in the course, attained more positive outcomes in the course including greater understanding and motivation. Similar results are shown in the work of Prince and Felder [17], in which they noted overall student academic achievement, perceptions, critical thinking, and analytic skills were more effective were achieved by the students whose classes incorporated the IBL approach. In another study by Spronken-Smith et al. [4] they noted that most modes of inquiry encouraged the students to develop their research and inquiry skills although the open inquiry mode was the highly rated course design by the students.

OUR APPROACH: FRAMEWORK ARCHITECTURE

Purpose: This study aimed to develop a framework that utilizes IBL approach to encourage undergraduate students in a four-year institution to cultivate their research skills through engaging in extracurricular research activities. The framework walks the students through scaffolded series of research tasks, with the guidance of the faculty researchers, as they utilize IBL processes to complete their research tasks. In this study, the authors describe the IBL-based framework to involve undergraduate aviation students in faculty-advised student-led research. Along with the framework, establishment of a student pipeline into research activities and some of their selected *next steps,* and their feedback on going through the process is also discussed.

Scope and Context: The researchers worked with students ranging from sophomores to senior undergraduate students and graduate students in guiding them completing various research activities depending on the students' level of expertise and area of discipline. While the researchers also work with graduate students, who had some levels of prior research experience, most undergraduate students had minimal research experience outside of coursework assessment activities that may involve research tasks at varying degrees. Therefore, the researchers develop an approach to help the interested undergraduate students develop the needed competence in conducting research activities. The researchers utilized a project-based learning type of IBL in which the students would learn how to come up with the research questions of their own, conduct the research to answer those questions, and present their findings to peers [18][19]. The students were enrolled in various majors including aviation management, aviation flight technology operations, computer science, and education. The range of academic disciplines in which the students were selected was crucial to support the various project tasks at hand conducted by the faculty researchers. As shown in Figure 1, the researchers utilized IBL approach to help the students complete the tasks. While it may be obvious for the faculty researchers to establish defined research questions, this may present a challenge for the students on how to pose quality research questions, and develop processes in addressing those questions.

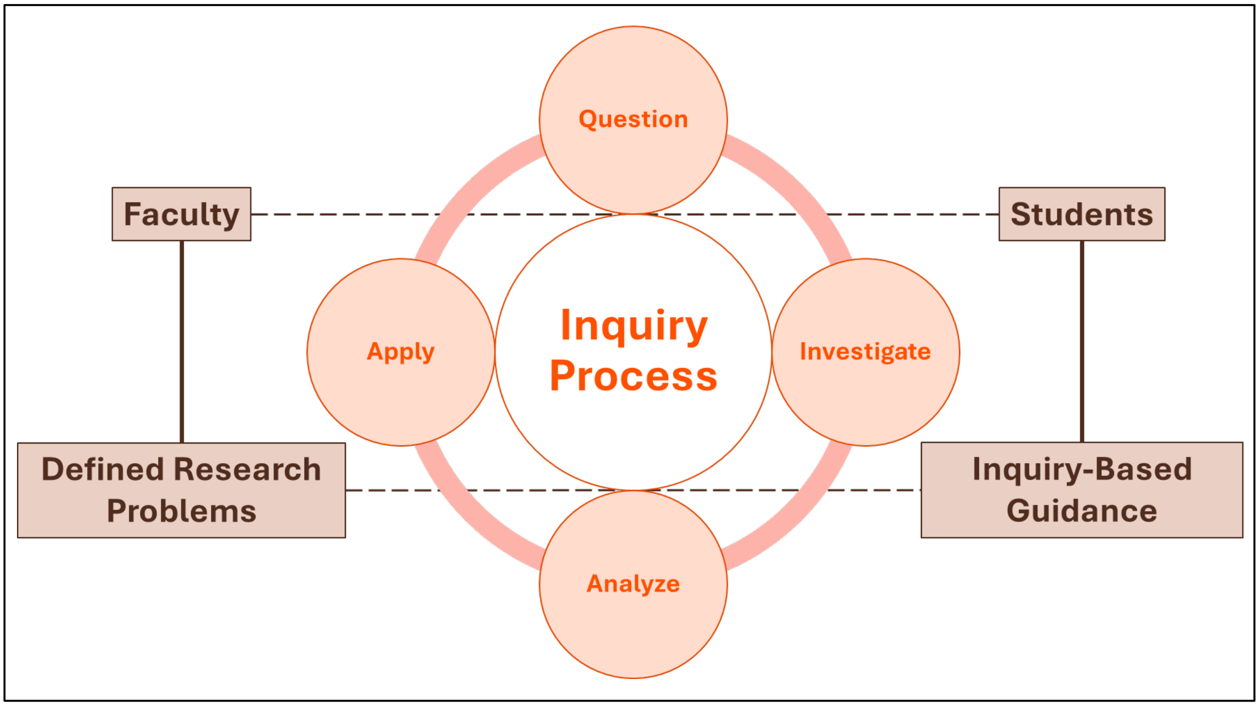

Figure 1. The Inquiry-Based Learning (IBL) process and the role of faculty and students involved in research activities.

In order for the faculty researchers to successfully establish a consistent pipeline of students participating in research projects, the integration process of students in the research was divided into two main steps. While the first step of the integration process would take about a semester to be completed, the second stage would span for several semesters. During the first step, faculty members guided the interested students in conducting systematic literature on various topics of interest. In the process, the students learned how to explore topics of interest, develop basic research questions, analyze literature sources, and ultimately perform a systematic literature review on a narrowed subject of interest. Additionally, during the first step of the process, both guided and open modes of inquiry were mainly utilized [4]. The students met with the researchers on a weekly basis in which they were provided with sub-tasks to complete. While the students had the knowledge of how to complete the tasks, the researchers guided them through the inquiry process so they can better and grow their research skills as they complete the tasks. In the initial weeks of working with the students, also as part of incentivizing the students, the faculty researchers encouraged the students to utilize the problem statements and established research questions to submit for undergraduate research funding opportunities within the institution. BGSU

Center for Undergraduate Research and Scholarship (CURS) [20] supports undergraduate students with $500 for qualified research expenses (for a team of up to two students, or up to $750 for a team of three or more) and a small stipend (typically, $200) for each student to help them complete their research projects during the semester. In addition, as a stipulation, students are required to present their findings at the annual BGSU Undergraduate Symposium for Research and Scholarship. As mentioned earlier, at this stage of our process, students mainly conducted systematic literature research studies – these studies ranged from advanced air mobility navigational corridors to utilization of artificial intelligence in advanced air mobility operations.

In the second step of the integration process, the faculty researchers worked with the existing student researchers in an on-going funded research project which already had assigned overall objectives and respective tasks. The Funded project had predetermined set of overarching research questions that the researchers were attempting to answer. As such, a structured mode of inquiry was utilized to guide the students in completing existing projects tasks [4]. Project tasks were mainly categorized into two areas: development of a supplementary hands-on curriculum to support the Unmanned Aerial Systems (UAS/drone) training and development of hands-on activities using Unity program. As part of the research project implementation to answer the research questions, the researchers engaged a team of student researchers to assist with completing various research tasks. The researchers utilized a scaffolding method in which the project tasks were broken down into smaller tasks that are regularly assigned to the students on a weekly basis. As shown in Figure 2, these weekly tasks would culminate into monthly deliverables in which the students finalized and presented their findings to the research agency that is funding the project. The students would then compile several monthly deliverables into one comprehensive report which is sent to the agency's technical advisory committee which provides oversight on the funded project. The deliverable reports address specific technical objectives which are directly tied to the overarching research questions that need addressing in the project. As such, the researchers explored an approach which combines both IBL and project-based learning (PBL) techniques to help students.

Student Feedback Data Collection and Analysis: Part of this study focused on collecting feedback from students to understand their perspective while being introduced to the practice of research under the inquiry-based learning approach. As such, an exploratory research approach was adopted based on the open, theory-building orientation to better understand the phenomenon in its natural context [21]. Assessing the students' progress, the faculty researchers utilized qualitative methods to capture the students' perspectives as they continued navigating through their assigned research tasks. Faculty researchers analyzed the students' feedback using thematic qualitative content analysis as it reflects the exploratory nature of the study [21].

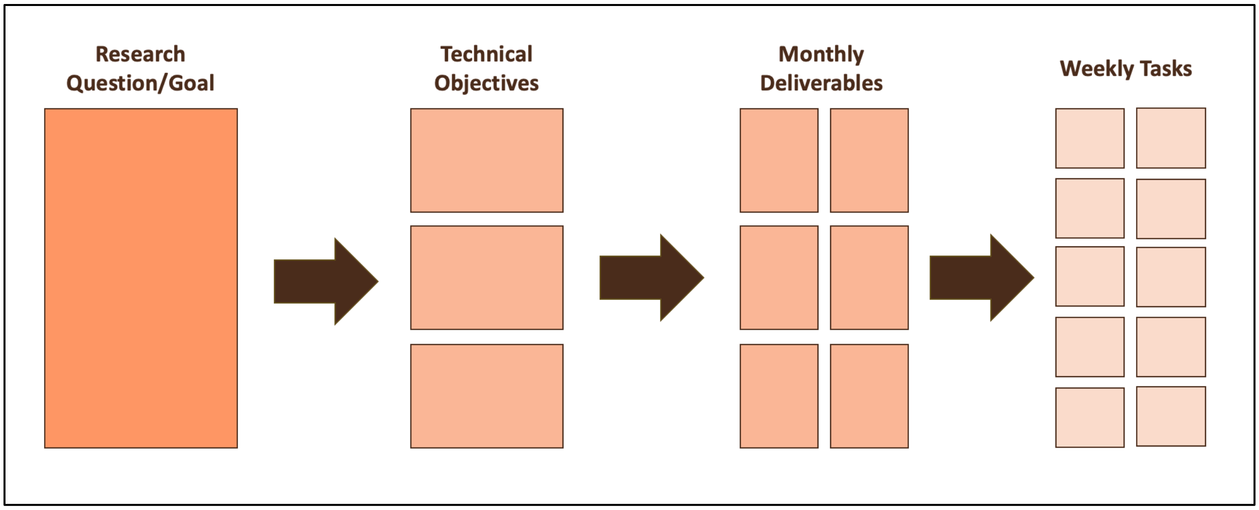

Figure 2. Breakdown of a larger goal (clearer and more understandable to the faculty) into smaller tasks (clearer and manageable to undergraduate students).

OUTCOMES AND DISCUSSION: Student Feedback

Within the scope of the framework and student research pipeline discussed in this paper, the authors were able to work with a total of 16 students between Fall 2024 and Spring 2026. Five of these students started with institutionally supported research projects (semester-long CURS projects) and were eventually hired as student researchers on an externally funded research project. Out of these five students, one also completed an Honor's Thesis while another one applied for and completed another CURS project. Six other students started with CURS projects and moved toward developing their projects into academic publications, Honor's Thesis, and/or national design competition proposals. There were four students who were recruited directly on the externally funded project as they were either graduate students with specific skills needed for the project, or had the experience to fit in the team. Of the 16 students who worked with the faculty members, 11 were able to provide detailed feedback on their research journey with the team. This section highlights the findings from a preliminary qualitative analysis of their feedback.

Students' feedback on going through the process of getting introduced to research, following an inquiry-based learning practice, and completing multiple research tasks, was centered around their successes and the challenged faced. From proud faculty advisors' perspective, our students' achievements include six internal undergraduate research grants, four honors projects, one national design competition, one externally-funded grant activities, and national scholarships.

Student Successes: Student feedback revealed transformative experiences, skill development, and career-defining outcomes.

<u>Early exposure to scholarly activity:</u> Participation in immersive, research-integrated aviation projects, including internal grant initiatives, external grant activities, CURS-funded projects, honors research, ACRP design competition activities, symposium presentations, poster presentations, and journal article preparation, yielded important

academic and professional outcomes. Students in the research teams demonstrated scholarly productivity, including conference and symposium presentations, grant participation, proposal development, prototype or design development, laboratory-based technical contributions, and report writing. These outputs provided students with early exposure to applied research workflows, faculty mentorship, external funding mechanisms, and professional dissemination, enhancing the legitimacy of their work within the academic community.

Skill development: Students reported skill development as a consistent outcome. Growth in teamwork and collaboration, particularly after navigating initial coordination challenges, was highlighted. Technical and academic competencies expanded through literature review practices, structured problem formulation, proposal writing, budget preparation, interview and survey development, hands-on development using tools such as Unity, and technical written and oral communication. Students also reported improvements in poster preparation, symposium presentations, networking, and the ability to communicate complex ideas to different audiences. In addition, students identified improvements in time management, long-term planning, and project organization, especially as they balanced research responsibilities with demanding flight training schedules, coursework, honors requirements, and other academic responsibilities.

Mentorship, belonging, and confidence: Several students described research participation as a pathway to mentorship, community, and greater connection within the aviation program. Faculty guidance helped students move from initial uncertainty toward greater academic independence, stronger confidence, and increased pride in their work. Students also reported that working with faculty and peers helped them feel more connected to the program and more capable of contributing to scholarly or professional conversations. This sense of belonging was especially important because many students entered the research process with limited prior understanding of research expectations, scholarly writing, or project development.

Transferable professional value: Student feedback also indicated that research participation helped students develop skills that they viewed as useful beyond research itself. Students connected proposal writing, grant applications, budgeting, professional writing, critical thinking, networking, presentations, and project planning to future opportunities such as scholarships, jobs, interviews, aviation careers, graduate study, and professional portfolios. This was especially important for students who did not necessarily plan to pursue research as a primary career path. Even students intending to become pilots, work in law enforcement, or pursue aviation administration described the research experience as valuable because it strengthened their ability to think critically, communicate professionally, work through complex problems, and present their work with confidence.

Change in perception: Importantly, students described the experience as personally and professionally transformative. Exposure to structured research environments, faculty mentorship, externally funded projects, industry-informed project development, and professional-style dissemination shifted perceptions of research from an abstract academic requirement to a viable and meaningful form of engagement with real aviation problems. For some students, this was the first time they envisioned graduate study, journal publication, academia, or research-oriented aviation careers as attainable professional trajectories. For others, the experience broadened their understanding of how research skills can support aviation practice, leadership, and future career development, even outside traditional academic research roles.

Student Challenges: Student feedback revealed both developmental challenges and structural insights relevant to program refinement.

Early-stage barriers: Many students reported initial confusion regarding research expectations, project direction, terminology, scholarly writing, and methodological rigor. Undergraduate participants, in particular, described a steep learning curve associated with research design, systematic literature reviews, proposal development, technical tool adoption, and scholarly communication. Some students also noted that research writing felt substantially different from ordinary academic writing, requiring them to learn a new language, structure, and standard of evidence. These challenges were amplified by concurrent academic, honors, work, and flight training demands.

Project structure and direction: Some students perceived early project phases as lacking clarity or visible impact, particularly in preliminary literature review, exploratory internal grant work, or early-stage project development. This occasionally led to reduced motivation until clearer milestones, deliverables, and project goals were established. Early team conflicts and ambiguity in role definition further complicated initial progress. These experiences suggest the importance of clear early expectations, structured check-ins, defined responsibilities, and visible short-term milestones within larger research projects.

Iterative project refinement: A theme that emerged strongly from the additional feedback was the challenge of repeated project refinement. Several students described research ideas changing substantially after additional literature review, faculty feedback, or conversations with industry experts. In some cases, students had to restart sections of their work, revise major parts of the project, or rethink the direction of the final design. Although this process was frustrating, students later recognized that these revisions improved the quality of the project and reflected the actual nature of research. This suggests that ambiguity and iteration should not be viewed only as weaknesses in project structure, but also as important parts of authentic inquiry when supported through mentorship and clear guidance.

Administrative and operational friction: Students expressed frustration with bureaucratic and procedural elements of grant-supported work, including documentation, proposal preparation, budget development, compliance requirements, repeated revisions, and formal submission processes. While these processes were ultimately educational and helped students understand how funded research works, they also contributed to perceptions of slow progress and additional workload. At the same time, several students recognized that learning to prepare proposals, budgets, and formal documents was valuable because these skills translate to scholarships, jobs, professional communication, and future project development.

Remote collaboration challenges. Communication breakdowns in virtual, hybrid, or schedule-constrained work environments emerged as a significant concern. In at least one case, misunderstandings nearly jeopardized a student's defined role within the team. Other students described the difficulty of coordinating meetings, dividing work evenly, communicating expectations, and maintaining progress when team members had different schedules and responsibilities. These experiences highlighted the necessity of structured communication protocols, explicit task ownership, regular check-ins, and clearer role definition during early project phases.

Affective responses. Students reported periods of anxiety, frustration, self-doubt, and uncertainty regarding their competence and the team's ability to complete ambitious research or technical objectives. These concerns were most prominent during early project stages, periods of slow visible progress, or moments when projects had to change direction substantially. However, students also described growth in confidence, pride, discipline, resilience, and comfort with ambiguity as they continued working through these challenges. This suggests that the mentoring process created productive struggle: students experienced research as difficult and sometimes uncomfortable, but also as a meaningful process through which they developed confidence, professional skills, and a stronger sense of their own capabilities.

CONCLUSION

This study presents preliminary insights into the implementation of an inquiry-based mentoring framework for engaging undergraduate students in aviation research. Student feedback suggests that the framework supported early exposure to scholarly activity, development of research and professional skills, increased confidence, and a stronger understanding of the research process. At the same time, the findings identified areas for refinement, including the need for clearer early-stage structure, role definition, communication practices, and support for students navigating ambiguity in research. Overall, the study suggests that intentional, inquiry-driven mentorship can help bridge classroom learning and authentic research engagement, while also strengthening students' academic confidence and professional preparation. Because the findings emerged from a specific aviation research environment, they should be interpreted as context-specific rather than broadly generalizable. Future work should examine the transferability of this mentoring framework across other disciplines, institutions, and undergraduate research settings.

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