

IUSE: Advancing Data Stewardship Education in Undergraduate Research: From Framework to Scalable Practice

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Abstract

As undergraduate research becomes increasingly data-intensive, students are often expected to plan, manage, document, and share data responsibly. Prior IUSE project work introduced a Data Stewardship Framework that integrates engineering design reasoning, data life cycle management, and ethical decision-making. This paper extends that work by examining how the framework has been translated into scalable instructional and mentoring practices across undergraduate engineering research contexts. Drawing on two years of implementation, we describe the development of a practical toolkit, the integration of stewardship into courses and research programs, and the use of a rubric to reinforce ethical data practices. Preliminary outcomes suggest that coupling conceptual frameworks with concrete tools and real-world examples can enhance undergraduate researchers' capacity for ethical data stewardship.

Introduction

Data now permeate nearly every stage of engineering research, from problem definition and experimentation to analysis, dissemination, and reuse. Undergraduate researchers are increasingly engaged in data-intensive projects, yet they often receive limited guidance on how to manage data responsibly, document decisions, or consider ethical implications beyond compliance-oriented training (Carlson et al., 2015). As a result, data stewardship, the care and management of data and information, is frequently learned informally, inconsistently, or too late in the research process.

To address this gap, our interdisciplinary team launched an NSF-funded IUSE project focusing on embedding data life cycle ethical management into undergraduate research in engineering and broadly in STEM. In prior work, we introduced a Data Stewardship Framework that integrates engineering design reasoning (Quintana-Cifuentes & Purzer, 2022), data reasoning (Wilkinson et al., 2016), and ethical decision-making (Beever & Brightman, 2016), to support conscientious decision-making across the research lifecycle (Purzer et al., 2024; Zakharov et al., 2025).

While the framework was well received, early pilots revealed that students and mentors needed more than conceptual guidance, they needed practical tools and real-world examples for application, and signals that stewardship is valued as part of research excellence. This paper builds on our earlier framework-focused work by examining how data stewardship has been operationalized in practice through toolkit development, instructional integration, and data stewards' recognition.

Practicing Data Stewardship in Courses and Research Programs

The toolkit has been implemented across multiple instructional and research contexts. A stand-alone undergraduate course, *Understanding Your Research Data*, applies data stewardship principles directly to undergraduate students' ongoing research projects. This course was designed and offered twice in Spring 2024 & 2025. Offered in hybrid format, the course engages students in planning, documenting, managing, visualizing, preserving, and ethically using their data. Students apply stewardship tools and examples to their own datasets and present their final research project posters at campus undergraduate research conferences. The course

now meets the university's requirements for the Undergraduate Research Certificate, which will be launched in Fall 2026.

Foundations of Data Management course provides a foundational understanding of data organization, management, preservation, and publication. The course enrolled 35 students in spring 2025 and 40 students in fall 2025, many of whom were pursuing a data science certificate. Throughout the course, students learned foundational knowledge and essential practices for ethical data management, equipping them with the skills necessary for responsible data handling in their future endeavors. In Fall 2025, students also started exploring AI data tools and ethical considerations of using these tools.

Beyond coursework, stewardship has been piloted into Vertically Integrated Projects (VIP) teams in the College of Engineering, where undergraduates collaborate with graduate students and faculty on multi-semester research efforts. In these settings, stewardship practices are reinforced through mentoring, shared documentation practices, and structured reflection.

Across these contexts, students practice stewardship not as a theoretical exercise but as part of authentic research workflows, supported by tools that align with engineering problem-solving and design processes.

Recognition and Mentor Perspectives

To reinforce the value of data stewardship, in Spring 2025, the project team officially launched the data stewardship awards at the Purdue Undergraduate Research Expo and Conference. The award named, "Data Stewardship in Applied Research," is the first initiative of its kind among 16 Big Ten consortium universities. The award is open to students presenting posters from the College of Engineering, College of Science, and Polytechnic Institute. The project team developed the award rubric and interview questions. In Spring of 2025, 35 undergraduate research teams applied, and three team awards were granted. This initiative not only recognizes excellence in data stewardship but also underscores the importance of ethical data management in advancing scientific research.

Graduate mentors play a critical role in shaping undergraduate research practices. Prior work shows that graduate mentors act as frontline guides for undergraduate researchers, strongly influencing day-to-day research behaviors (Dolan & Johnson, 2009). Our study with graduate mentors revealed persistent challenges in documentation, metadata creation, and data preservation, even when technical skills were well developed. These findings underscore the importance of equipping mentors with data management tools and shared language, enabling them to model and reinforce responsible data management practices consistently (Arigye et al., 2026).

Preliminary Outcomes and Implications

Across two years of implementation, more than 200 undergraduates have engaged with data stewardship through courses, workshops, and research teams. Student reflections indicate increased confidence in managing data-intensive projects and greater awareness of ethical responsibilities. Mentors report improved structure for discussing data practices and decision-making with students.

These outcomes suggest several implications for engineering education. First, conceptual frameworks are necessary but insufficient; they must be paired with practical tools that support application. Second, mentorship is a powerful leverage point for embedding stewardship into research culture. Third, recognition mechanisms such as data stewardship awards can reinforce desired practices and signal institutional values.

Conclusion

As engineering research becomes increasingly data-driven, preparing undergraduate researchers to act as ethical data stewards is essential. This paper demonstrates how a data stewardship framework can be translated into scalable practice through toolkits, instructional integration, and recognition mechanisms. By embedding stewardship into authentic research contexts and mentoring relationships, undergraduate research programs can foster ethical, sustainable data practices that extend beyond individual projects. Future work will focus on longitudinal and rigorous assessment and broader dissemination of these approaches across undergraduate research programs.

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