Implementing the AI-Lab Framework: Enhancing Introductory Programming Education for CS Majors

Andres Bejarano*
Purdue University
West Lafayette, Indiana, USA
abejara@purdue.edu

Ethan Dickey*
Purdue University
West Lafayette, Indiana, USA
dickeye@purdue.edu

Rhianna Kuperus
Purdue University
West Lafayette, Indiana, USA
rsetsma@purdue.edu

Abstract

The advent of generative AI tools presents novel opportunities and challenges in computer science education, particularly in introductory programming courses. This study explores the implementation of AI-Lab, a framework designed to guide students in the effective and ethical use of generative AI, in this case ChatGPT, in academic settings without compromising skill development. Conducted during Spring 2024, our use of the intervention targeted over 500 Computer Science and Data Science majors enrolled in their major-specific Data Structures and Algorithms courses.

The AI-Lab framework enabled students to develop both conceptual questions and c++ and Python programs by interacting with ChatGPT and iteratively correcting its errors. Focus groups and post-intervention surveys revealed a generally positive experience. Students appreciated the ability to leverage AI for tasks outside their major, recognizing the value of understanding correct solutions through AI-assisted programming. Moreover, the guided use of generative AI by professors alleviated concerns regarding academic dishonesty, fostering a supportive learning environment.

Despite these benefits, students expressed awareness of the potential drawbacks of over-reliance on AI, noting the risk of impeding their professional growth. Nevertheless, they acknowledged the practical utility of AI for non-major related tasks. This study highlights the importance of incorporating structured AI training in curricula to balance skill development and ethical AI usage, offering insights for broader applications in higher education.

ACM Reference Format:
Andres Bejarano, Ethan Dickey, and Rhianna Kuperus. 2025. Implementing the AI-Lab Framework: Enhancing Introductory Programming Education for CS Majors. In *Proceedings of the 56th ACM Technical Symposium on Computer Science Education V. 2 (SIGCSE TS 2025), February 26-March 1, 2025, Pittsburgh, PA, USA.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3641555.3705201

1 Introduction

Generative AI tools like ChatGPT have revolutionized how subjects are taught, particularly in specialized courses such as Data Structures and Algorithms. Recognizing the potential of these tools to both aid and compromise educational integrity, this study focuses on the controlled integration of AI into computer science and data science curricula, aiming to enrich student learning while maintaining essential skill development.

Research specifically studying the impact of GenAI on student learning is still in its infancy. Habib et al. investigated the effect of GenAI on student creativity, noting both negative impacts on creative confidence and potential support for creative thinking [3]. Similarly, Yilmaz and Yilmaz found that GenAI positively influenced computational thinking, self-efficacy, and motivation, making it an effective tool for teaching programming [4]. Additionally, a survey by Codio.com revealed frequent use of AI tools among students in computing courses, although the sample was skewed towards older participants (71% being 30 or older) [1].

This paper builds on these studies, presenting data from an implementation of the AI-Lab intervention in an introductory programming course for computer science students (as the AI-Lab itself does not have any reported data). Our findings contribute to the ongoing discourse on the educational potential and challenges of integrating GenAI into the curriculum.

2 The AI-Lab Framework

The AI-Lab framework, introduced by Dickey *et al.*, is designed to integrate Generative AI (GenAI) tools into educational settings to enhance learning outcomes. The primary goals of the AI-Lab are to familiarize students with the effective use of GenAI, highlight its limitations, and stress the importance of developing robust skills that extend beyond the capabilities of AI assistance [2].

The AI-Lab begins by encouraging students to use GenAI to answer course-content-based questions and deepen their understanding of course material. As the lab progresses, it introduces more complex problems that GenAI cannot solve accurately, illustrating the risks of over-reliance on AI tools and emphasizing the need for fundamental skill development. The lab concludes with a session where students reflect on their experiences, critically assessing the limitations of AI and the implications for their learning.

The framework aims to promote equity in education by enabling all students, regardless of their prior exposure to such technologies, to proficiently use GenAI tools. This approach helps to bridge the gap between students and ensures a more equitable educational experience. The AI-Lab framework is adaptable, requiring only that certain structural guidelines be followed, including the introduction of best practices, experiential learning through success and failure, and reflective activities post-intervention.

*Both authors contributed equally to this research.

SIGCSE TS 2025, February 26-March 1, 2025, Pittsburgh, PA, USA

ACM ISBN 979-8-4007-0532-8/25/02
https://doi.org/10.1145/3641555.3705201

3 AI-Lab Experience with CS and DS Students

This section of the poster will discuss the implementation of the AI-Lab during the Spring 2024 semester. Over 500 students participated, using ChatGPT to assist in developing both conceptual understanding and practical programming skills in C++ and Python. The experience was structured to foster not only knowledge acquisition but also critical thinking about the role of AI in problem-solving.

4 Survey Data and Insights

The authors would like to note here that the original AI-Lab paper did not include any specific data, so the novelty of this poster will be presenting data associated with a trial run of the AI-Lab itself.

This section of the poster will present comprehensive survey data collected from over 500 students enrolled in CS251 and CS253 during Spring 2024. Students were mostly sophomores in CS taking their Data Structures and Algorithms class. Tests revealed no correlations across measured demographics. Students were provided a bonus for completing all 4 surveys (2 pre, 2 post), but were not required to do so. The results will highlight changes in student perceptions and usage of generative AI tools before and after the intervention, with specific focus on:

- Student Engagement and Changes in Usage:
  - Post-intervention results indicated an increased comfort with identical openness to using GenAI for conceptual questions and debugging, though less so for homework problems, suggesting a nuanced view of GenAI's role in learning. Indeed, while there was a decrease in openness for use in debugging, there was a statistically significant increase in the frequency of use of GenAI in debugging.
- Perception of AI's Effectiveness:
  - Analysis of how students' engagement with GenAI evolved through the semester, showing a significant decrease in the openness of GenAI use for debugging and mostly little effect on openness of use for conceptual questions and homework.
  - Students reported high levels of comfort using GenAI to assist with conceptual questions post-intervention, suggesting increased trust in AI's ability to support learning in complex subject areas.
- Concerns and Challenges:
  - Thematic analysis of textual analysis highlighted a large range of opinions and perspectives on GenAI usage in and out of the classroom. Potential challenges mentioned included inaccuracy and misleading students as well as over-reliance.
  - Furthermore, students had concerns about the integrity of their classmates, with a significant number of students wary of potential academic dishonesty.
- Statistical Analysis:
  - Presentation of detailed statistical tests, including the Wilcoxon Signed-Rank Test and Cliff's Delta, to underscore the quantitative changes observed.
  - The analysis will focus on the significant improvements in debugging and conceptual understanding, contrasting them with the areas where no significant changes were observed.
- Visual Representations:
  - Besides visually representing the previously reported data, the poster will include a graphical depiction of students' reported frequency of GenAI use across different programming tasks, illustrating trends and shifts in usage patterns.

5 Discussion

Overall, the AI-Lab framework was well-received by students. The structured approach to integrating GenAI tools, particularly ChatGPT, into the learning process was effective and engaging. Students reported a high level of comfort and openness towards using GenAI tools post-intervention, with a significant majority expressing an increased desire to use these tools for academic assistance. This perception aligns with the objectives of the AI-Lab, which aimed to familiarize students with GenAI capabilities while highlighting the necessity of critical thinking and problem-solving skills.

One of the primary concerns in integrating AI tools in education is the potential for over-reliance, which might hinder the development of fundamental programming skills, culminating in a theorized phenomena [2] termed the Junior Year Wall. The AI-Lab framework addresses this by structuring activities that require students to engage with the AI outputs critically. By guiding students to iteratively correct errors generated by ChatGPT, the framework ensured that students remained active participants in the problem-solving process. This approach not only demystified the workings of AI but also reinforced the importance of understanding underlying concepts rather than passively accepting AI-generated solutions.

The AI-Lab intervention shows that with careful design and implementation, GenAI tools can be a valuable addition to the educational toolkit. Educators can prepare students for a future where AI is an integral part of their professional and academic lives by enabling an environment where students adequately learn the power of AI while maintaining a solid foundation in essential skills. This experience provides a blueprint for such integrations in programming courses for CS students, highlighting both the potential and the challenges of teaching with AI in today's educational landscape.

Acknowledgments

This work was funded by Purdue's Innovation Hub (IH-AI-23002). The authors also acknowledge the Teaching Assistants from CS251 during Spring 2024 who graded the AI-Lab assignment portion and managed questions. The authors finally thank Purdue's Institutional Data Analytics and Assessment as well as the Center for Instructional Excellence, both of whom were instrumental in the success of this project.

References

[1] Codio.com. 2024. Student Perspectives and Use of Generative AI in Post-Secondary Computing Education. *Whitepaper* (2024).

[2] Ethan Dickey, Andres Bejarano, and Chirayu Garg. 2024. Innovating Computer Programming Pedagogy: The AI-Lab Framework for Generative AI Adoption. *Accepted for publication in Springer Nature Computer Science* (2024). https://doi.org/10.1007/s42979-024-03074-y

[3] Sabrina Habib, Thomas Vogel, Xiao Anli, and Evelyn Thorne. 2024. How does generative artificial intelligence impact student creativity? *Journal of Creativity* 34, 1 (2024), 100072.

[4] Ramazan Yilmaz and Fatma Gizem Karaoglan Yilmaz. 2023. The effect of generative artificial intelligence (AI)-based tool use on students' computational thinking skills, programming self-efficacy and motivation. *Computers and Education: Artificial Intelligence* 4 (2023), 100147. https://doi.org/10.1016/j.caeai.2023.100147