Enhancing CS Education with LAs Using AI-Empowered AIELA Program

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***Abstract*—This innovative practice full paper delves into the transformative role of Learning Assistants (LAs) in Computer Science education, focusing on enhancing student engagement and improving learning outcomes. The LA model, which aligns with Vygotsky's Social Constructivist Learning Theory, fosters an environment of student-centered learning and social interaction. In a pilot study conducted in Spring 2024 at a public university, the LA program is implemented in two computer science courses. A quasi-experimental design has been used to evaluate the impact of LA-facilitated team activities on student learning outcomes. The study compares a control group receiving traditional instruction with an experimental group participating in LA-facilitated team activities. The experimental group engaged in weekly team-based activities, guided by LAs and faculty, to reinforce class concepts and promote collaboration among team members. Student engagement and learning have been evaluated using feedback from students and LAs collected through Discussion Boards (DBs). Preliminary findings suggest that LA-facilitated in-class activities promote active learning and enhance problem-solving skills. LAs provide valuable support and guidance to students, particularly those struggling to understand complex concepts. The study tested a working model of AIELA, an innovative AI-powered chatbot that *assists* human LAs in supporting students through knowledge-reinforcing questions and multimodal data analysis, powered by OpenAI API's gpt-4-turbo model. This research is a step towards embracing the challenges of modern CS education, inspiring further innovation in this critical field. The findings will benefit educators seeking innovative strategies to enrich student engagement and learning in engineering and computing disciplines.**

***Index Terms*—Learning Assistant model, active learning strategies, Artificial Intelligence-enabled chatbot, student engagement.**

I. Introduction

Generative artificial intelligence (AI) applications like ChatGPT have revolutionized teaching and learning methodologies, emphasizing the need to address the diverse learning needs of students from varied backgrounds, experiences, and skill sets with adaptable educational approaches. Our research explores the evolving landscape of Computer Science (CS) education using the Learning Assistant (LA) model [1]. LAs are undergraduate students facilitating collaborative active learning among student groups in classroom settings to enhance student engagement and learning outcomes.

Active learning has been shown to enhance student performance on assessments and concept inventories in Science, Technology, Engineering, and Mathematics (STEM) classrooms [25], [43]. This model demonstrates that collaborative peer discussions improve understanding, even when none of the students initially know the correct answer [10]. When active learning is supported by LAs, students are more successful, with even greater improvements observed among historically underrepresented and marginalized student populations. This finding aligns with the study by Theobald et al. (2020), which highlights the importance of intentional, focused, scaffolded, and repeated practice in active learning strategies for enhancing student success [25].

The LA program is designed to improve undergraduate education by engaging capable undergraduate students in the teaching and learning process. The LA program aims to foster a sense of belonging among students to help them succeed in a field often perceived as intimidating. Typically, LAs are high-achieving undergraduate students who have already excelled in a course and received training to assist instructors and promote active classroom learning. Although implementing the LA model may differ from institution to institution, the fundamental idea of involving undergraduate students in supporting and facilitating education in their respective fields is a common feature. The LA model is part of a broader movement in higher education that promotes active learning, student-centered teaching, and peer-led instruction to enhance the educational experience for students. The LA program is an excellent example of how universities explore innovative teaching and learning methods to improve student success in

STEM disciplines and beyond.

The LA model has been successfully implemented in various universities, resulting in noticeable improvements in student performance and engagement. LA model trains research assistants to provide undergraduate students with valuable hands-on experience in academic research, which is crucial for promoting undergraduate research and STEM education [26]. The impacts of the LA program include greater learning gains, persistence within a course and to graduation, a sense of belonging for students, long-term content understanding for LAs, and course transformation for faculty [27]–[29].

The LA model is a collaborative, peer-assisted teaching approach in STEM education that benefits students and LAs [11]. While prior research has focused on the advantages for students, this study also examines the transformative effects experienced by LAs. The impact of LA programs on undergraduate LAs in STEM classes is examined, revealing enhancements in LAs' metacognition and motivation. The study uses a pretest-posttest design and finds that the program improves LAs' reflective learning skills, intrinsic motivation, and self-efficacy. We attended the International Learning Assistant Conference (ILAC-2023), which focused on empowering the LA community.

Aligned with the Social Constructivist Learning Theory by Vygotsky [30], LA-facilitated team-based worksheets promote experiential learning, contextualized problem-solving, and social interaction. The roles of LAs are pivotal in guiding students through complex concepts and encouraging teamwork to tackle challenging problems. They provide support and guidance as students engage in team-based hands-on activities fostering a supportive learning environment, encouraging students to ask questions, explore different solutions, and learn from each other's answers and perspectives about the concepts.

We propose to utilize evidence-based active learning practices with the LA model, known as the International LA Alliance (ILAA) [6], which has been implemented in over 3,000 universities and college campuses worldwide. The LA model was created and developed at the University of Colorado Boulder (CU Boulder) during the 2000s. Since then, it has been adopted and adapted by several other institutions around the globe. Over the years, it has evolved as more universities have recognized the benefits of using undergraduate LAs to improve teaching and learning, increase engagement in STEM fields, enhance student learning outcomes, and provide valuable teaching experience to undergraduate students.

Highlighting the advantages of using LA programs for students and LAs leads to whether AI chatbots can offer similar benefits as human LAs. Implementing chatbots in education has emerged as a promising method to enhance learning experiences and outcomes. AI-powered chatbots are programmed to interact with students through natural language conversations, providing personalized assistance and support. Electronic Chatbots (ECs) improve learning performance and facilitate teamwork, indirectly influencing team performance by enhancing collaboration [31]–[33]. One of the significant benefits of ECs is their ability to provide immediate and personalized support to students. Chatbots can use AI algorithms to analyze students' responses and tailor their interactions to address individual learning needs.This personalization helps students understand complex concepts effectively and at their own pace. An AI-enhanced learning assistant (AIELA) chatbot designed to augment human LAs is introduced. It provides knowledge-reinforcing questions, assists students in achieving their learning goals, and analyzes multimodal data.

To achieve two important learning objectives - (i) enhancing student collaborative and active learning using LAs and (ii) designing an AI-enhanced LA model, this study proposes the following research questions that utilize evidence-based techniques to achieve learning outcomes.

RQ1: How does participation in Learning Assistant (LA) programs impact student learning and engagement in computer science education?

RQ2: How can the role of LAs be optimized to improve student engagement and learning outcomes in STEM courses using AI-based intelligent virtual assistants?

Thus, this research is a step towards embracing the challenges of modern CS education, inspiring further innovation in this critical field. The findings will benefit educators seeking innovative strategies to enrich student engagement and learning in engineering and computing disciplines.

The remainder of the paper is structured as follows. Section 2 provides an overview of the Learning Assistant (LA) model and its popularity in educational environments and examines the role of educational chatbots in promoting student engagement discussed in the literature. Section 3 describes the proposed Human AI and the impact of human LAs in computer science courses and introduces the AIELA Framework. In Section 4, the experimental analysis of the impact of human LAs on student engagement and learning is followed by a discussion of the experimental results. Finally, the summary of findings and the future directions are outlined in Section 5.

II. Background

Promoting student engagement techniques is paramount to ensuring improved student learning and performance in the ever-changing realm of education. This section describes the Learning Assistant (LA) model integrated with student-centered active learning based on pedagogical research. From the scientific innovation perspective, this section also explores using an AI-enabled LA model to augment human LAs.

A. IRMAR Model

To highlight the importance of effective teaching practices in student engagement, belonging, and retention, we propose the iterative IRMAR model as shown in Figure 1(a). This student-centered learning model includes five components to ensure student success: Introduce (I), Reinforce (R), Master (M), Assess (A), and Reflect (R). The IRMAR model, which follows a student-centered learning pedagogy, includes several steps. The first step involves sparking interest while ***introducing*** the content and ensuring equitable access to resources for all students. This step encourages students to explore the

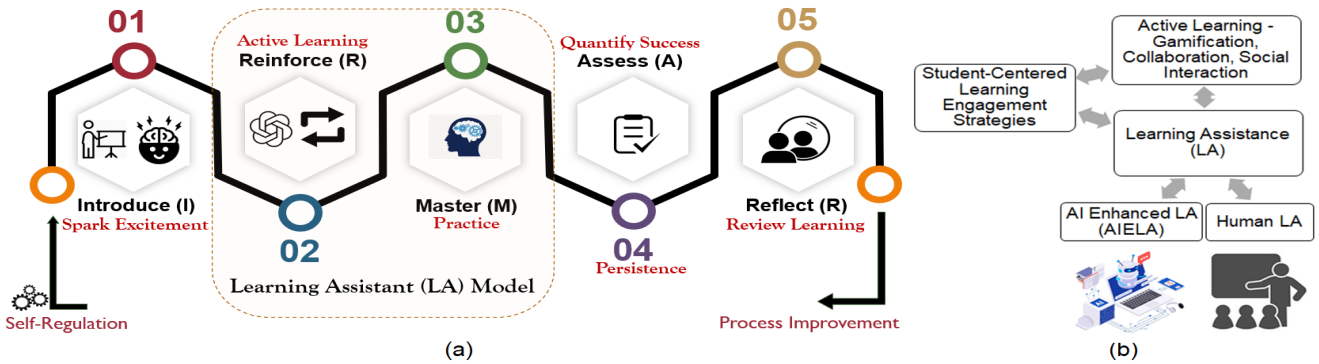

Fig. 1. IRMAR Model to (a) **I**ntroduce (see, visualize, hear), **R**einforce (hands-on activities), **M**aster (logical reasoning), **A**ssess (analyze), and **R**eflect (consistent feedback) - leveraged with Learning Assistant (LA) Model; (b) Human and the proposed AI Enabled LA (AIELA) Models

knowledge gained by seeing, visualizing, and hearing the content. It also promotes self-regulation and reinforces learning through deliberate practice, which includes logical reasoning and cognitive skills [46]. The next two steps of ***reinforcing*** and ***mastering*** concepts of the model use the Learning Assistant (LA) Model to build student confidence and motivate active learning. Peer-assisted teaching models using LAs have been explored by many researchers and have proven to be effective. The next step is ***assessing*** student performance to quantify student success, which provides insights, allowing educators to adjust their approach and refine their teaching methods based on student feedback. Quantifying student success and adapting teaching strategies are integral to this step. The final step of the model is ***reflection***, where students and educators engage in dialogues, reviewing their learning experiences and identifying areas for improvement. This reflective process refines understanding and informs future iterations of the learning cycle, resulting in process improvement. The following subsections emphasize the significant role of the LA model in student engagement and improved performance, gaps in human LA programs, and the role of educational chatbots/virtual assistants in education.

B. Learning Assistant Model

The **Learning Assistant (LA)** model has gained prominence as an innovative pedagogical approach that not only benefits students but also positively impacts the LAs themselves [20]. Rooted in collaborative learning and peer-assisted teaching, this model engages undergraduate students as LAs. While existing research has highlighted the advantages of LA-supported classes for students, our focus here is on the transformative effects experienced by the LAs—the very architects of this dynamic educational ecosystem.

The concept of learning assistance evolved when academic preparatory institutes emerged as a bridge for college aspirants in the mid-1880s. These academies created academic preparatory departments, which became essential to college curricula. While tutorial programs were common in prestigious institutions such as Harvard and Yale, academically underprepared students faced challenges in less selective institutions. To meet their needs, separate academic departments, such as the first modern learning assistance program at the University of Wisconsin in 1849, were created. Instead of relying on external preparatory academies, Wisconsin created an academic department specifically for remedial courses and hired a separate faculty to teach them [14]. Since then, the learning assistance program continued to evolve. In the late 20th century, the role of LAs became more formalized, with the University of Colorado Boulder leading the way in developing the LA Model. This model involved organizing peer facilitation to improve student learning, focusing on physics. Studies showed that classes with LA support increased learning outcomes, particularly for women and minorities [15], [16]. Several universities have implemented successful LA Programs. For instance, the evidence-based LA program in the Sciences at the University of California, Los Angeles (UCLA) is designed to enhance key aspects of courses such as faculty scalability, student satisfaction, and instructional improvement.

LAs promote active learning and collaborative instruction in discussion, lab, and/or lecture settings [1], [17]. At the Oregon State University's LA Program, the LAs provide faculty with support for implementing high-impact teaching practices in class, including active learning, frequent formative assessment, and personalized feedback for students [18]. A scoping review of the literature evaluated the impact of the LA model and its goals suggesting that the LA model has the potential to bring about transformation in education. Further research may provide more insightful information about its impact [19]. Research studies have been conducted to evaluate the effects of LA programs on undergraduate students who serve as LAs in STEM classes. Another chemical education study showed the LA program's benefits in evaluating students' interests, effort beliefs, and self-efficacy [44]. The program could improve LAs' reflective learning skills and increase scores on the Metacognitive Awareness Inventory (MAI) after the first quarter, indicating improvements in LAs' metacognition. Additionally, LAs demonstrated improvements in intrinsic motivation and self-efficacy. When LAs continued their participation in the LA program, there were further increases in MAI scores and sustained gains in motivation. The findings suggest that LA programs not only benefit students but also have a positive impact on the LAs themselves [20].

C. Challenges and Gaps in Human LAs

Studies have shown that traditional LA models, where peers serve as educators, can positively impact student success. This model has also been found to improve equity in the classroom by increasing learning gains for all students, regardless of their demographics. However, there are still some challenges and gaps in existing approaches as listed below [43] [44]. (i) *Scalability:* With increasing class sizes and diverse student groups, it becomes challenging for a group of LAs to provide personalized support to all students since it is crucial to ensure the quality of support provided by LAs as the program expands. This lack of personalized attention can lead to some students not receiving the help they need. (ii) *Availability:* While the LA programs show increased learning and course outcomes, these interventions impact the support outside classrooms since the LA support is available for a limited time in the class. (iii) *Quality of LA support:* Managing many LAs in a classroom setting can be challenging as it becomes difficult to provide consistent and effective training to all of them. The quality of support offered by LAs may vary based on their comprehension of the subject matter and their ability to conduct meaningful discussions among students. (iv) *Assessment of learning:* With large class sizes, it can be challenging to assess individual student learning and provide timely feedback, which is crucial for student learning and progress. Traditional assessment methods may not work well or be practical in such settings. Therefore, addressing these challenges requires continuous research by exploring new strategies and tools to enhance the effectiveness of the LA model in large and diverse classrooms.

D. Augmenting LAs with AI-Enabled Virtual Assistants in Education

The technology of Chatbots was invented in the 1960s, and it aims to have natural and intelligent conversations with humans using AI. This communication software can be easily found worldwide, including in education. Most universities have Chatbots on their websites for better availability and responsiveness. Furthermore, the preference for chatbots from students gets larger while they less prefer communication with others. With chatbots' increasing supply and demand, this field has enormously expanded [36].

Siti and Mazlina presented guidelines for developing an AI-based smart chatbot for a university website. In the examination, they found chatbot components within the academic field and common patterns of existing chatbots for university websites. They also identified the necessity of a cloud service to ensure that the chatbot contains large datasets. However, they also discovered the lack of validation due to improper databases, which must be addressed [35]. A study was conducted in Introductory MIS courses to evaluate the potential of chatbots as intelligent student assistants in education. The study used a user-centered design approach, and two studies were conducted to assess the effectiveness of chatbots in teaching content and engaging students. The first study gathered student perceptions of learning needs and explored the strengths and challenges of chatbots, while the second study introduced a new chatbot to teach AI concepts. The findings indicate that chatbots can effectively teach basic content, encourage resource exploration, and enhance student engagement. Despite the challenges in replicating human interaction, students found chatbots responsive and effective in providing feedback. The research highlights the potential of chatbots as valuable learning assistants while acknowledging the challenges of imitating human mannerisms [21].

Many educational chatbots provide students with helpful information and even assist them with homework. However, while these chatbots have a lot of potential, they can sometimes hinder a student's learning ability. To ensure that students can still learn and not just get easy answers, limiting the chatbot's functionality to provide relevant information rather than directly answering the user's input is important. The following section discusses the proposed research study by describing the study design, data collection techniques, and human LA vs. AIELA virtual assistant/chatbot initiative.

III. Proposed Methodology

A. Study Design

In a pilot study in Spring 2024 at a public university, we implemented the LA program in two computer science courses. We use a quasi-experimental design to assess interventions and demonstrate causality between interventions and outcomes without using randomization. We also evaluate the impact of LA-facilitated team activities on the student learning outcomes in these courses. The LAs were trained using the prep sessions and LA seminars. The study involves a control group of students (Spring 2023) who received traditional instruction taught by the same faculty members without LAs, and the experimental group of students (Spring 2024), who are involved in LA-facilitated team activities. To ensure the validity of our findings, it's important to note that there were no changes in course content, teaching methods, or team activity worksheets, except for using LAs in Spring 2024. This supports the evidence that any observed differences can be attributed solely to the intervention. To ensure the validity of our findings, it's important to note that there were no changes in course content, teaching methods, or team activity worksheets, except for using LAs in Spring 2024. This supports the evidence that any observed differences can be attributed solely to the intervention. The LA program workflow Fig 2 used in our project is iterative and incremental.

The iterative LA model workflow begins with faculty preparing course materials, designing team-based, active learning assignments aligned with learning objectives, and incorporating LA support. Potential student LAs who have completed the course successfully are recruited and trained on course content, pedagogical strategies, and team facilitation. The LAs guide weekly team-based activities by supporting and guiding students, particularly those struggling with complex concepts, to enhance their understanding and problem-solving skills. This on-time guidance helps reinforce class concepts, promote collaboration, and encourage active learning among

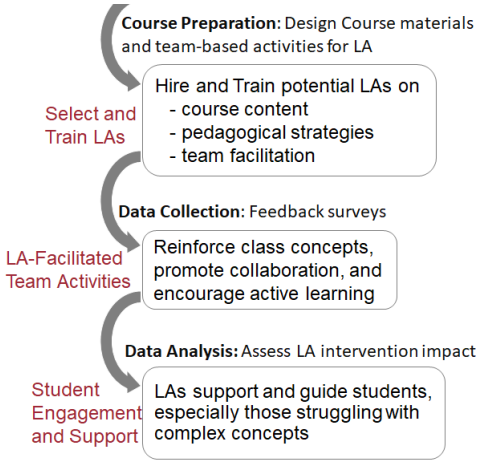

Fig. 2. LA Program Workflow

team members. LAs often collaborate with faculty to lead discussions, facilitate group activities, and provide peer support to their fellow students. The experimental group participated in weekly team-based activities, guided by LAs and faculty, to reinforce class concepts and promote collaboration among team members. Feedback from students and LAs on the effectiveness and impact of these activities is gathered through Discussion Boards (DBs), offering insights into student engagement and learning. Preliminary results indicate that LAs facilitating team activities promote active learning and enhance problem-solving skills.

B. Data Collection

We recruited LAs to assist students in developing critical thinking skills and building confidence in their ability to solve complex problems related to programming and data structures. Multiple survey instruments collect feedback from students and LAs for evaluating LA-facilitated activities. The data is analyzed to assess the impact of LA interventions on student learning outcomes and engagement. The analysis results shed light on adjusting the "iterative" LA model, course design, or activities, ultimately improving effectiveness and student outcomes. Providing ongoing support and training for LAs and continuously evaluating the LA model ensure its relevance and impact on student success. The data used in this study were collected from $Spring$ 2024 of Computer Science I $(CS-1)$ and Data Structures and Algorithm Design $(CS-3)$courses at a small public university. The details of the number of students who participated in the LA activities in the CS-1 and CS-3 courses are presented in Table I. The performance data collected from Spring 23 students (CS-1: 16, CS-3: 36) is used as a control group, where the students did not participate in the LA-based team activities. However, they were engaged in the team-based worksheet activities. The same worksheets were used in Spring 2024 to ensure consistency in data collection. Therefore, the performance of these students was considered as the benchmark data. $Spring$ 2024 semester data represent the treatment group where the students are involved in weekly team-based LA activities for 10 weeks. The students reflected on the fifth and tenth weeks of the LA activities using the Qualtrics (*https://www.qualtrics.com*) reflection survey. It served as a platform for the students to share their learning experiences during the course by posting their views on the different LA-based discussion topics and questions related to the information presented in the course [45]. The analysis included student reflection data, online discussion forum data, and final grades from the treatment group; for the control group, only the final grades were considered for analysis.

TABLE I
LEARNING ASSISTANT PROGRAM PARTICIPATION - SPRING 2024

	Variables	CS-1	CS-3	Total
N	Participated	19	27	46
	Not Participated	1	4	5
	Total Enrollment	**20**	**31**	**51**
Percent Distribution %	Participated	95.0	87.1	90.2
	Not Participated	5.0	12.9	9.8
	Total Enrollment	**100**	**100**	**100**

To continue investigating the challenges and gaps in enhancing the effectiveness of the LA model in supporting student learning and success in large and diverse classrooms, we propose to create AIELA, a chatbot designed to augment human LA by ensuring students stay engaged while learning. Integrated with the OpenAI API's get-4-turbo model, AIELA will provide knowledge-reinforcing questions instead of direct answers like human LAs, helping students achieve their learning goals and help analyze multimodal data (audio and chat: think aloud protocol, text: discussion board data).

C. AIELA Framework

The development of AIELA was initiated to augment traditional learning environments by integrating sophisticated AI to support and enhance the educational process. This section details the practical implementation, reflects on the observed interactions, and outlines future enhancements based on our findings. The preliminary prototype of AIELA has been built and tested. Fig. 3 showcases the current framework and the future enhancements planned for building the AI-enhanced Chatbot that augments the human LAs.

Our initial approach involved deploying AIELA using a Raspberry Pi as the interface for interaction, where students could enter queries via text or speech. This setup, as depicted in Figure 3, utilizes OpenAI's API to process queries through the gpt-4-turbo large language model. The system prompt formulated for AIELA was designed to encourage AI responses that facilitate student understanding without directly providing solutions, thereby promoting critical thinking. The AIELA chatbot will benefit students, instructors, and LAs by allowing interpretation of the student's learning progress and reflection on teaching methodologies.

IV. RESULTS AND DISCUSSION

In this section, we present the results of the student surveys to evaluate the effectiveness of Learning Assistants (LAs) and their impact on their learning experiences, the prototype of AIELA, and future enhancement plans.

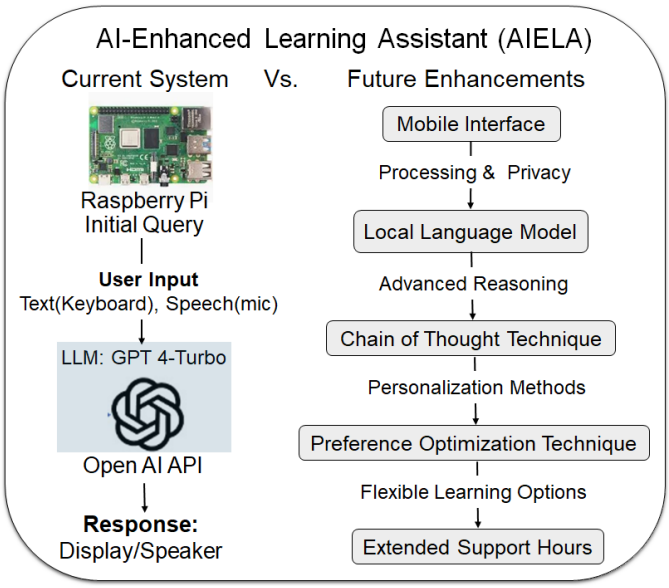

Fig. 3. AIELA - Current System and Future Enhancements

TABLE II
AVERAGE STUDENT SURVEY SCORES FOR LAS TEAM-BASED ACTIVITIES

Categories of Survey Questions	Avg. Score
Learning Assistants' Impact	
LA effectiveness rating	4.20
LAs were approachable and responsive	4.25
LAs positively contributed to learning experience	4.75
LA assistance was beneficial in improving performance	4.40
LAs effectively addressed misconceptions/gaps	4.10
LA-based Worksheet Assignment Effectiveness	
LA support in assignments	4.10
LA-assisted activities helped acquire more knowledge	4.35
Difficulty level of LA-facilitated worksheets	3.80
Interaction with LAs	
Felt comfortable asking LAs for help	4.60
LA Interaction for help or clarification frequency (per activity)	3 times
Feedback and Suggestions	
LA assistance improved team effectiveness	4.25
Would like to see more LA-supported assignments	4.65
Recommend LA program in other CS courses	4.55
Suggestions to improve LA role	4.00

A. Student Reflection Survey on Impact of LAs

The survey aimed to collect feedback on various aspects of LA-led activities, such as their efficacy in helping students comprehend course material, promoting team-based learning, and enhancing problem-solving and critical-thinking skills. Moreover, the survey examined students' comfort level in interacting with LAs, the perceived fairness of LA time allocation, and the overall contribution of LAs to students' learning experiences and engagement with the course material. The results provided valuable insights into LAs' effectiveness in enhancing student learning and engagement and areas for potential improvement in LA-led activities. The average scores (out of 5) from the student survey results on the impact of the LA program on student learning, grouped into four categories, are presented in Table II. It addresses our **RQ1** on the *impact of the LA program on student learning and engagement in computer science education.*

Student perception survey data suggests that the LA program positively affects student learning outcomes and increases participation rates. A 'think aloud' protocol also captures student collaboration and peer learning data. The feedback indicates that the LAs and the LA program have positively impacted students' learning, engagement, and teamwork. Most students found the LAs effective in helping them understand course material and improve problem-solving skills. Furthermore, students expressed that engaging in team-based learning activities greatly contributed to their comprehension of concepts and improved their ability to work in teams. They were comfortable interacting with the LAs and found them approachable and responsive. Many students desired more LA-oriented assignments and activities in future classes. However, some students suggested improving the role or effectiveness of LAs by providing more exercises and increasing their availability outside of class. The survey results indicate a positive perception of the LA program's effectiveness. The key findings, with average student ratings on a scale 5 in parentheses are: ***Increased Engagement:*** Students reported a high level of engagement in LA-facilitated activities (4.25); ***Improved Understanding:*** The role of LAs in enhancing the understanding of course material was highly valued (4.45); ***Enhanced Collaboration:*** The collaborative nature of the activities was appreciated by students (4.3); and ***Valuable Learning Experience:*** Overall, students found the learning experience valuable (4.4).

Based on the ratings received, the students find LA-facilitated activities engaging, beneficial for their understanding, conducive to collaboration, and valuable for their overall learning experience. This positive feedback highlights the effectiveness of the LA program in facilitating student learning and positively impacting students, improving their learning experience, engagement, and teamwork. Furthermore, areas for improvement have been identified to further enhance the effectiveness of the LA program in future courses.

The effectiveness of the LA program in improving student performance was evaluated by comparing the final grade distribution for the control group in Spring 2023 and the treatment group in Spring 2024. There was only a slight increase in the final grades in the CS-1 courses. The observations and inferences based on the grade distribution data from these two semesters for CS-3 are illustrated Fig. 4. Implementing LA-

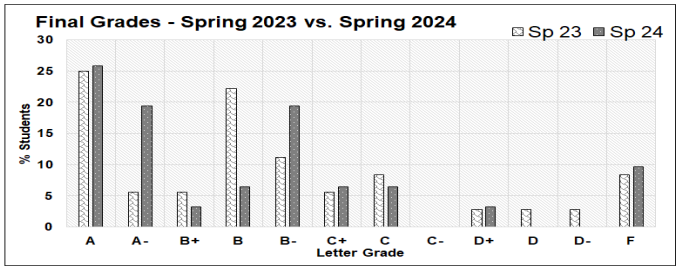

Fig. 4. Grade Distribution Report for CS-3 - Spring 2023 vs Spring 2024

based team activities in Spring 24 in CS-3 seems to have positively impacted student performance, evident from the increase in A- grades from 5.56% in Sp 23 to 19.35% in Spring 24. The percentage of A grades remained relatively stable, slightly increasing from 25% in Spring 23 to 25.81% in Spring 24. This suggests that high-achieving students remain consistent with the introduction of LA-based activities. There was a significant increase in B- grades from 11.11% in Spring 23 to 19.35% in Spring 24, and a corresponding decrease in B and B+ grades. The percentages of D+, D, and D- grades decreased in Spring 24, suggesting a reduction in lower performance levels. This could be attributed to the LA-based activities' additional support and collaborative learning opportunities. However, the percentage of F grades increased slightly from 8.33% in Spring 23 to 9.68% in Spring 24 due to other factors, such as student attendance and engagement levels influencing these results. However, further research would be beneficial to understand these trends and their implications.

Our experiment and the student reflection survey to validate the effectiveness of LA compared student performance and claimed improved performance when LA-based collaboration activities were used, based on a comparison of students in the Spring 2023 course sections to those of students from Spring 2024. However, it is important to note that many factors can influence student performance, including difficulty with the course content, individual student aptitude, and engagement levels. Therefore, while LA-based activities seem to have had a positive impact, further research, and continuous assessment are necessary to understand their effectiveness and make definitive conclusions. Furthermore, although both groups had the same instructor and syllabus, we did not attempt to balance demographic characteristics.

B. AIELA Prototype - Observations and Future Enhancements

This subsection addresses **RQ2** on *optimizing the role of LAs to improve student engagement and learning outcomes in STEM courses using AI-based intelligent virtual assistants.* The deployment of AIELA in CS-1 classroom settings for two assignments highlighted several behavioral insights. Initially, students hesitated to use the system, likely due to its novelty and the public nature of the interaction. However, as usage became more common, this hesitation decreased significantly. Using a single Raspberry Pi revealed scalability issues, particularly during peak times, which informed our decisions for future enhancements. The data was not included in this article because only limited data was collected. As the field of AI-enhanced learning assistants advances, a transition to mobile interfaces is recommended to enhance privacy and facilitate more accessible interactions, addressing both scalability and accessibility concerns. Additionally, integrating local language models is advised to enhance operational independence from continuous internet connectivity and bolster data privacy.

Our future work will focus on expanding the scope and depth of the LA program. We aim to pursue exploratory research to (i) Extend the deployment of the AIELA framework across multiple institutions to assess its effectiveness in diverse educational environments, (ii) Investigate the long-term impacts of continuous AI and human LA support on student performance, retention, and graduation rates, (iii) Develop and integrate more sophisticated AI models that can provide even more personalized support and predictive analytics to anticipate student needs, and (iv) Evaluate the comparative benefits and potential drawbacks of AI-based LAs versus traditional human LAs in a broader range of disciplines.

We also consider evaluating advanced reasoning techniques such as Chain of Thought [37], Tree of Thought [38], and Graph of Thoughts [39]. These methodologies are designed to enhance the AI's problem-solving capabilities, making it a more effective partner in learning. Additionally, exploring personalization techniques such as Reinforcement Learning from Human Feedback [40], Direct Preference Optimization [41], and Mixed Preference Optimization [42] could drastically improve AI systems' capacity to adapt responses based on individual student feedback and preferences, thereby enhancing the personalized learning experience.

A critical area for future development is implementing a conversation history mechanism. Currently, interactions with AI-enhanced learning assistants like AIELA are processed independently, without any retention of conversations in the past. This statelessness restricts the continuity essential for educational dialogue, often hindering deeper learning engagements. A conversation history feature would enable these systems to provide contextually aware responses and build on previous interactions, significantly boosting their effectiveness as educational tools. This capability is crucial for supporting students in progressively understanding complex concepts through sustained dialogues rather than isolated queries.

V. Conclusion

The research study tested LA-facilitated team activities with the goal of reinforcing class concepts and promoting collaboration among team members. Student engagement and learning were evaluated using feedback from students and LAs collected through Discussion Boards (DBs). Preliminary findings indicate that LA-facilitated in-class activities promote active learning and enhance problem-solving skills. LAs provide valuable support and guidance to students, especially those who are struggling to understand complex concepts.

Through the integration of human and AI-powered LAs, like AIELA, we could demonstrate the potential to significantly enhance the educational experience. This approach supports active learning and aligns with the pedagogical shift towards more interactive, student-centered education models. The preliminary prototype of AIELA will be extended using rich open AI code as a mobile application. It will produce promising results in fostering student engagement and enhancing learning outcomes, particularly in complex concept comprehension and problem-solving skills. The paper takes a step towards defining engineering and computing education methodologies in light of the challenges of modern CS education. While we plan to gather extensive data for analyzing the impact of LAs, our pilot study will inspire further explorations and

innovation in this critical field using AI-enabled technology solutions. Our findings will benefit educators seeking innovative strategies to enrich student engagement and learning in engineering and computing disciplines. We are currently developing methodologies that blend AI's benefits with the irreplaceable human elements of teaching. Our aim is to create an optimal educational ecosystem that supports all students, especially those from underrepresented backgrounds.

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