VizGroup: An AI-Assisted Event-Driven System for Real-Time Collaborative Programming Learning Analytics

Xiaohang Tang
Virginia Tech
Blacksburg, Virginia, USA
xiaohangtang@vt.edu

Sam Wong
University of Washington
Seattle, Washington, USA
samw627@uw.edu

Kevin Pu
University of Toronto
Toronto, Ontario, Canada
kevin.pu@mail.utoronto.ca

Xi Chen
Virginia Tech
Blacksburg, Virginia, USA
xic@vt.edu

Yalong Yang
Georgia Institute of Technology
Atlanta, Georgia, USA
yalong.yang@gatech.edu

Yan Chen
Virginia Tech
Blacksburg, Virginia, USA
ych@vt.edu

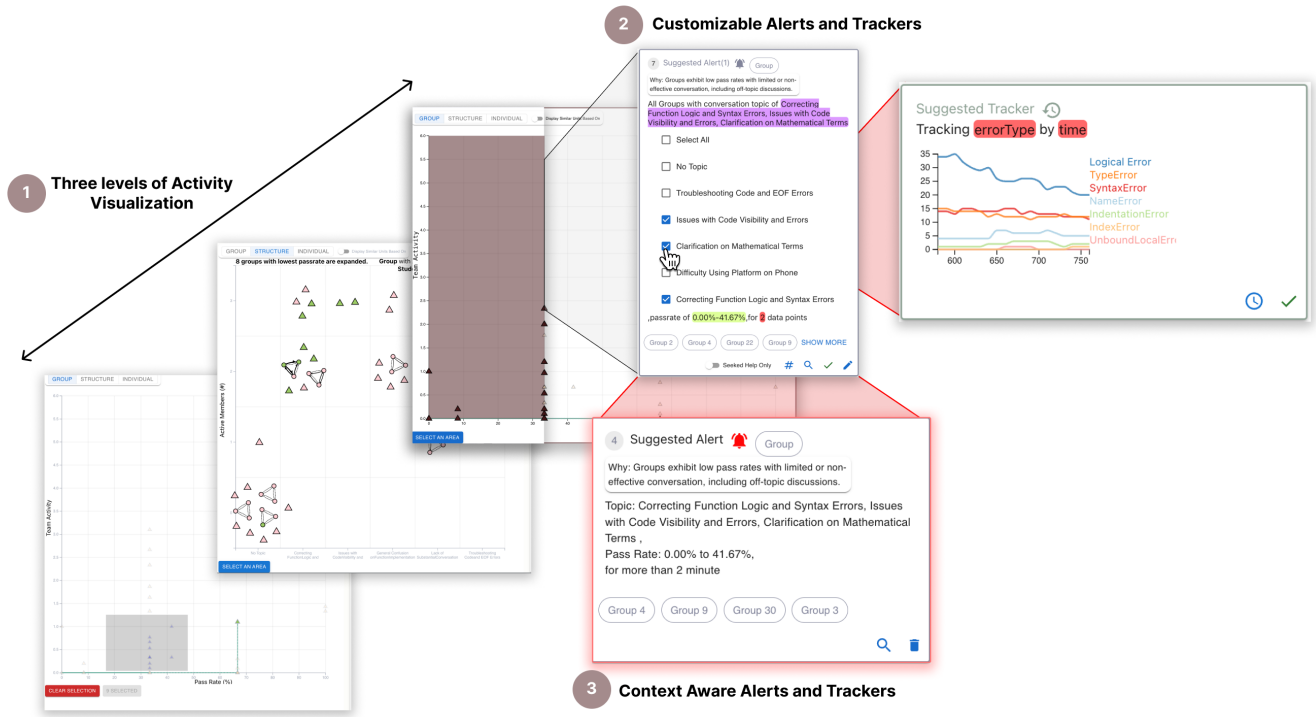

Figure 1: VizGroup, an LLMs-assisted system for real-time collaborative learning analytics, visualizes student performance and collaboration via a dynamic 2D scatter plot and provides proactive notifications for timely interventions.

ABSTRACT

Programming instructors often conduct collaborative learning activities, like Peer Instruction, to foster a deeper understanding in students and enhance their engagement with learning. These activities, however, may not always yield productive outcomes due to the diversity of student mental models and their ineffective collaboration. In this work, we introduce VizGroup, an AI-assisted system that enables programming instructors to easily oversee students' real-time collaborative learning behaviors during large programming courses. VizGroup leverages Large Language Models (LLMs) to recommend event specifications for instructors so that they can simultaneously track and receive alerts about key correlation patterns between various collaboration metrics and ongoing coding tasks. We evaluated VizGroup with 12 instructors in

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a comparison study using a dataset collected from a Peer Instruction activity that was conducted in a large programming lecture. The results showed that VizGroup helped instructors effectively overview, narrow down, and track nuances throughout students' behaviors.

KEYWORDS

Programming Education, Collaborative Learning

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1 INTRODUCTION

Students' active collaboration with peers while learning can promote engagement, deepen their understanding of concepts, and enhance their problem-solving skills [55]. In Computer Science Education, peer learning activities such as group discussions [41], pair programming [50], code reviews [24], peer instruction [16], and peer assessments [56] have been employed to foster cooperative learning environments. Peer Instruction (PI), for example, is an in-class instructional strategy that emphasizes students' active construction of a conceptual understanding with their peers [16]. During peer instruction, students first individually respond to a question (i.e., write and submit their code independently), then discuss their code with peers, modify their code, and finally re-submit it. Peer instruction has been shown to be effective at reducing failure rates, improving retention, and enhancing exam performance across various fields, including computer science [6, 38, 46, 48, 54].

Although numerous studies have highlighted the benefits of PI, prior work has advocated for guidance during peer collaboration [59] and recommended that teaching staff should manage pair interactions in programming labs [61]. Yet, it is challenging to design effective management tools to assist instructors in conducting PI activities in large programming classes where large volumes of data about groups can be generated. We argue that this is largely because the interplay between discussion and learning outcomes during a PI session has received less attention, making it difficult to identify and observe meaningful learner interaction patterns. It is unclear if all discussions positively impact overall learning outcomes or if ineffective communication can hinder progress [47]. By developing tools that enable instructors to better observe and be aware of these interaction patterns, they could begin to understand the relationship between discussion and learning outcomes in the context of their specific courses.

Tools, such as visual analytics (VA), i.e., the combination of automated analysis and interactive visualizations, have shown promise in identifying patterns in large-scale data [9, 34, 35]. While most visual analytics (VA) tools support offline analysis of previously collected data, they often lack real-time analysis capabilities [11]. This limits instructors' ability to provide immediate, data-driven interventions that could enhance collaborative performance, particularly when unexpected behavior patterns emerge. Other systems, such as Groupnamics [52] and Pair-Up [63], have explored the effects of real-time collaboration analytics, but they did not adequately address the need to analyze the relationship between group collaboration and learning outcomes at scale. The increasing volume and complexity of data generated during collaborative learning activities can overwhelm instructors, hindering their ability to identify and track events that demand time-sensitive attention. Meanwhile, recent advances in Large Language Models (LLMs) have demonstrated the potential to perform real-time data analysis at scale, but it is unclear how to effectively use LLMs to organize and present the information in an intuitive way for collaborative learning analytics.

To investigate the specific design needs and challenges instructors face, we deployed a technology probe in a large programming class (100+ students) where the instructor conducted a PI coding exercise. Our exploration highlighted that (1) instructors need to be able to easily track multiple patterns of correlation between collaboration and the coding exercise in real-time, (2) they need to be informed about emerging patterns in group activity over time, and (3) they need to be able to get a sense of how interaction patterns correlate with the future success of the groups. These findings underscore the importance of designing systems that support instructors in managing collaborative learning environments by enabling them to monitor multiple types of information without being overly constrained by a prescribed approach.

Based on these findings, we developed VizGroup, an LLMs-assisted system that streamlines the process of overseeing real-time collaborative learning analytics during a programming lecture. VizGroup displays and updates a 2D scatter plot that visualizes collaboration information and students' performance in near real-time. After inputting user interactions (e.g., clicking on a topic) and urgent patterns found in historical data (e.g., groups not chatting after a new code issue occurs) into an LLM, VizGroup will proactively recommend *notifications* (i.e., intelligent monitoring units) that track specific metrics and alert users to important changes or patterns in the data.

To assess VizGroup's usability and effectiveness, we conducted a between-subject study with 12 participants with teaching experience. Participants used a basic visual analytics tool without a notification system and then used VizGroup with or without our LLM recommendation notifications. The results showed that compared to a version of VizGroup without the notification recommendation, VizGroup with suggested units helped instructors create additional monitoring units that were previously undiscoverable on their own. These recommendations covered a more diverse range of metrics, providing a more comprehensive understanding of the learning process. Furthermore, we found evidence that the suggested notifications influenced the participants' decision-making when selecting the following monitoring unit criteria. Our research makes the following contributions:

- Design implications from our formative study that aim to enhance instructors' capacities to monitor and comprehend class-wide collaboration dynamics as they occur.
- A new approach that uses contextual information, such as user interactions and real-time data changes, to generate recommendations for tracker and alert creation for novices while using real-time learning visual analytics.

- VizGroup, a novel AI-assisted monitoring system for collaborative learning analytics that streamlines the monitoring of key patterns in data via intelligent, context-aware notification creation.