PaperPal: An AI-Powered Platform for Collaborative Reading and Discussion

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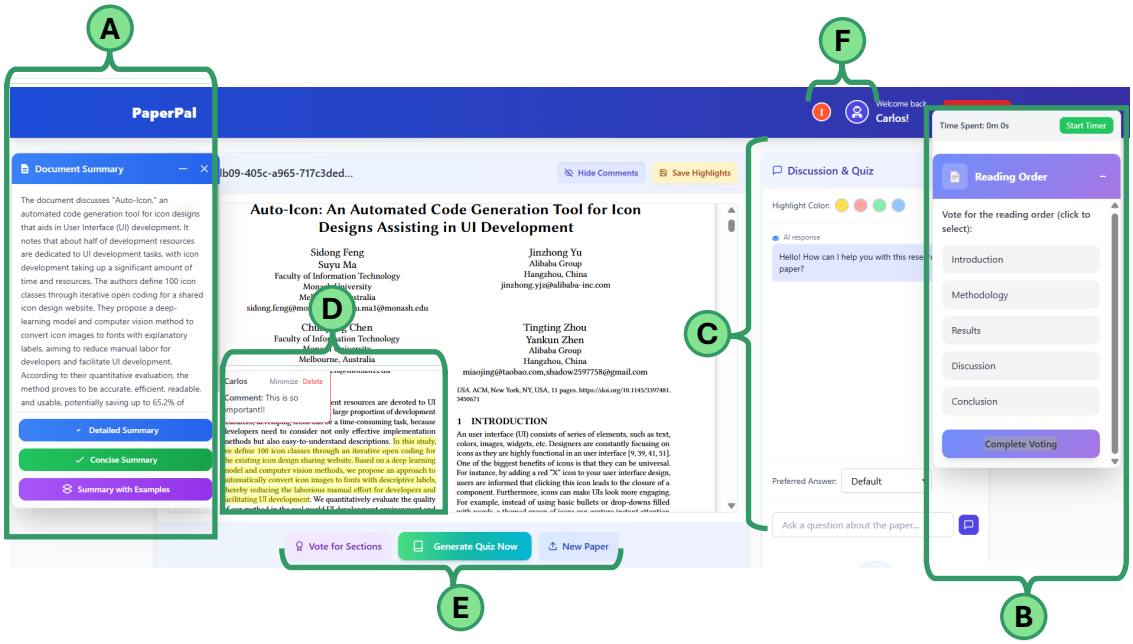

Fig. 1. Overview of the PaperPal Interface (A) Dynamic Summary allows you to adjust the detail level in AI-generated summaries for each section of the paper. (B) Voting and Quiz lets you vote for the next section and take quick quizzes. (C) AI Help and Chat provides live chat and immediate AI assistance. (D) Collaborative Annotation enables everyone to highlight text and add comments together. (E) Action Toolbar gives quick access to essential commands. (F) User Profile Controls show who is active and let you manage your activity and profile.

Collaborative learning with research papers is crucial for academic growth, yet the applications available today rarely provide the engaging and effective experience needed for collaborative learning. We propose a solution that simplifies working with academic papers while making the experience interactive and helpful. This paper introduces a platform designed to transform how groups collaborate on research papers, making the process more dynamic, intuitive, and productive. The system integrates real-time collaborative annotation, AI-generated tools, layered explanations, adaptive quizzes, and structured discussion workflows, all powered by large language models (LLMs). It tracks engagement and highlights key focus areas based on collective user behaviour. Our early implementation demonstrates the potential of generative AI to meaningfully enhance academic group learning by making it more inclusive, intelligent, and participatory. Through this work, we aim to explore how large language models and AI integration can transform collaborative academic tools, fostering deeper collaboration and understanding.

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CCS Concepts: • **Human-centered computing** → **Collaborative and social computing systems and tools**; **Computer supported cooperative work**; • **Computing methodologies** → *Natural language processing*; • **Information systems** → *Recommender systems*; • **Applied computing** → Interactive learning environments.

Additional Key Words and Phrases: Collaborative Learning, AI-Guided Reading, Academic Paper Interaction, Real-Time Annotation, Group Learning Platform

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1 Introduction

Collaborative reading and discussion of academic papers are powerful ways for learners to unpack complex ideas, make connections, and build shared understanding [9]. However, the process is often held back by practical challenges. The tools commonly used like PDF readers, messaging apps, video calls, and shared documents are scattered across different platforms and not designed to work together. As a result, discussions can lose focus, misunderstandings go unaddressed, and participation tends to vary depending on each person's background, confidence, or interest [2, 3].

Recent progress in generative AI, particularly large language models (LLMs) like GPT-4[1], offers promising ways to address these challenges. LLMs can explain difficult concepts from multiple angles, summarize dense content, track learner engagement, and recognize signs of confusion, enabling timely, tailored support. However, current systems have notable limitations. EduChat [2] helps structure group discussions but may suppress quieter voices due to overly direct prompts. MAI Flow [3] uses rule-based triggers to detect group confusion but lacks fine-grained personalization. Mibi [4] supports emotional well-being through self-disclosure, yet offers little academic feedback. Co-Pilot [5] enables customizable classroom agents, but outcomes often vary due to reliance on user-authored dialogue flows.

We present PaperPal, an AI-powered platform for collaborative academic reading. It integrates real-time highlighting, shared annotation, AI-generated summaries, comprehension checks, and embedded chat into a single environment. As users engage with papers, the AI monitors interaction patterns such as reading pauses, annotation density, and chat activity to provide context-aware support. It can clarify confusing sections, surface relevant examples, or summarize key points in real time. Readers also have interactive options: they can toggle between explanation formats, vote on which section to read next, and receive short quizzes to check their understanding. Based on responses, PaperPal delivers targeted support and encourages stronger readers to assist peers. By combining generative AI with structured group tools, PaperPal transforms academic reading into a more focused, interactive, and inclusive experience. Figure 1 provides an overview of the platform's core features.

2 Background and Literature Review

In this section, we review AI tools that support collaborative learning, focusing on their design, capabilities, and limitations to identify progress and challenges in enhancing group learning experiences.

[1] https://openai.com/gpt-4

2.1 AI for Collaborative and Personalized Learning

Recent research highlights the growing role of AI in both group collaboration and personalized learning. Systems like EduChat use large language models (LLMs) to guide group discussions, applying frameworks such as ICAP to keep conversations productive and encouraging quieter participants to contribute [2]. However, its limited ability to adapt to individual learning needs makes it less effective in unstructured or diverse group settings. MAI takes a different approach by detecting confusion and disagreement during group conversations and offering prompts to steer the discussion [3]. While useful, it lacks deeper personalization and often delivers generic feedback that may not reflect each learner's unique context. Similarly, VizGroup visualizes collaborative dynamics in programming education [8], but it depends heavily on instructors' interpretations and doesn't directly address the causes of disengagement or conflict.

On the personalization side, tools like AgentCF tailor recommendations to individual learner preferences [10]. Yet, LLMs can misinterpret complex user behaviors, leading to mismatches between recommendations and actual learner needs. In learnersourcing environments, AI-generated feedback can increase engagement [7], but it also introduces risks such as learners over-relying on AI, especially when the quality of feedback is inconsistent or difficult to assess. Blending AI with human guidance offers a more promising path. Coaching Copilot, for example, combines AI-generated reflections with mentor input to support leadership development [1]. Still, LLMs struggle with nuanced conversations that require empathy or long-term understanding, underscoring the continued importance of human involvement in AI design. Similarly, Co-Pilot allows educators to customize AI agents for their classrooms [5], but it assumes a level of technical fluency that may exclude non-expert users. Another approach, known as *solve-then-refine*, encourages learners to attempt problem-solving before consulting AI, promoting independent thinking [6]. However, learners often struggle with knowing when to seek help, and vague or inconsistent AI responses can reduce trust over time.

These challenges point to a common theme: effective AI systems must balance personalized support with collaborative awareness while preserving learner independence and building trust. Our system treats AI as a collaborative partner rather than a director. It steps in after learners have made their own attempts, offers adjustable levels of support, and combines real-time feedback with context-aware prompts and collaborative annotation. This design supports both individual understanding and group discussion, while avoiding over-reliance on automation and keeping users meaningfully involved throughout the process.

3 Proposed Solution

In this section, we introduce PaperPal, an AI-powered platform that helps groups read and discuss academic papers more easily and effectively. PaperPal is designed to make group reading more interactive and engaging. This section explains the platform's main features and how they support better collaborative learning and discussion.

3.1 AI-Enhanced Interactive PDF Interface

PaperPal features an interactive PDF viewer that enables real-time group reading and collaboration. Unlike traditional static viewers, it allows participants to engage and annotate the document synchronously. Built using the open-source `@react-pdf-viewer` [2], PaperPal enhances this viewer with annotation tools, custom toolbars, and synchronization features. As a result, all highlights, comments, and navigation changes are instantly reflected across participants' screens, ensuring a seamless collaborative experience.

[2] https://react-pdf-viewer.dev/

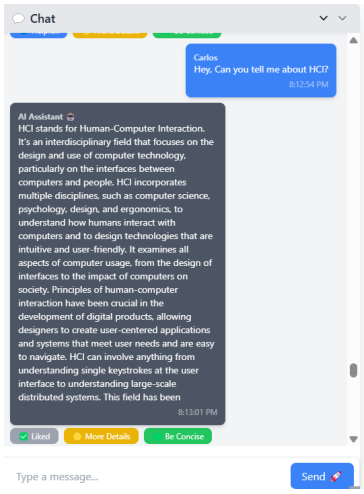

Fig. 2. The AI-guided chat interface in PaperPal. Users engage in real-time discussion alongside the paper while the AI assistant provides context-aware responses based on the current section. The assistant can offer clarifications, summaries, or prompts to support ongoing dialogue and ensure balanced participation.

Once a PDF is uploaded, it opens in a shared space where users can highlight text, add comments, and reply within the document. Annotations are immediately visible to everyone, tagged with usernames and timestamps, though users can opt to keep their highlights private. To ensure consistency across different devices, highlights are aligned using percentage-based bounding boxes.

While reading, the system monitors user interactions, such as frequent highlights or discussions. If a section generates significant attention or confusion, the system flags it and offers additional explanations, tailored to the group's needs. These may include brief summaries or detailed examples. Over time, the system learns from user feedback, refining its ability to identify sections requiring further clarification in future sessions.

All annotations and AI-generated explanations are saved directly into the PDF using `pdf-lib`[3], a JavaScript library for editing PDFs in the browser. This creates a persistent, revisitable document enriched with collaborative insights and contextual support, transforming passive reading into an active, socially-informed learning process.

3.2 Real-Time Chat with Embedded AI Support

PaperPal includes a real-time group chat integrated with the PDF viewer, enabling users to communicate while reading the paper (see Fig 1.C). The chat system is powered by Firebase, which ensures real-time message delivery, facilitating continuous and uninterrupted collaboration during the reading process.

The chat features an embedded AI assistant, powered by GPT-4, which provides context-specific help. Users can ask questions, and the AI will respond with answers tailored to the current section of the paper and previous chat messages. For example, asking "Can you explain the methodology section?" will prompt the AI to give a detailed explanation based on that exact section, rather than a general response.

[3] https://pdf-lib.js.org/

Additionally, users can provide feedback on AI responses by rating them with thumbs-up or thumbs-down, requesting simpler explanations with "Be Concise," or asking for more information using "More Details." This feedback helps the AI improve over time to better suit the group's needs.

Furthermore, to ensure active participation, the AI monitors for inactive users and sends friendly nudges, such as "Would you like to share your thoughts?" or "Feel free to ask a question if anything is unclear," helping everyone stay engaged without pressure. All chat messages, including AI responses and feedback, are saved with timestamps and usernames. Users can revisit important discussions and explanations later. The chat also supports markdown formatting and links directly to sections of the paper, keeping conversations organized and relevant to the content.

3.3 Tunable AI Summarization Engine

Upon uploading a paper to PaperPal, the system automatically generates AI-powered summaries through a multi-step process. First, `pdf.js`[4] is used to extract and clean the content of the PDF, removing unnecessary elements like metadata, headers, and footers. This ensures that only the main body of the paper is processed. The cleaned text is then sent to GPT-4, which produces tailored summaries based on different reading needs (Fig 1.A).

The summarization engine is tunable, offering users four summary styles: a general overview in natural language (default), a concise version focusing on key points, a detailed version that closely mirrors the paper's structure, and an example-based version using analogies or simple scenarios. Users can toggle between these formats at any time to adjust the level of detail to their preferences.

These summaries are displayed in a side panel next to the main PDF viewer, allowing easy reference without disrupting the reading flow. By providing varied levels of depth, the summarization engine supports diverse learning styles, helping users better understand complex material, whether through brief overviews, detailed breakdowns, or example-driven explanations.

3.4 Structured Reading with Section-Wise Voting and Comprehension Checks

Coordinating reading progress in collaborative sessions can be challenging when participants have varying interests. To address this, PaperPal introduces a section-wise voting system that sets the reading order at the start of the session. Before beginning, participants vote on the sections they want to read, and the system arranges them in the most preferred order. This ensures that everyone's input is considered and the group stays organized throughout the reading process (Fig 1.B).

To further enhance understanding, PaperPal automatically generates a short quiz after each section, powered by GPT-4. This quiz consists of five multiple-choice questions based on the content just read, designed to assess comprehension without interrupting the reading flow. The results are immediately processed, and the system provides feedback to users, helping them gauge their understanding and reinforce key concepts. Fig 3 illustrates the quiz results and AI-generated feedback.

If a user scores poorly, the system offers personalized support by providing simplified explanations, clarifications, or suggestions to revisit the relevant part of the paper (Fig. 3.A). Conversely, users who score well are encouraged to write a short summary or explanation of the section, which is then shared with the group to facilitate peer learning and reinforce the material (Fig. 3.B). . This allows those who scored poorly to pair with high-performing peers for additional support.

[4] https://mozilla.github.io/pdf.js/

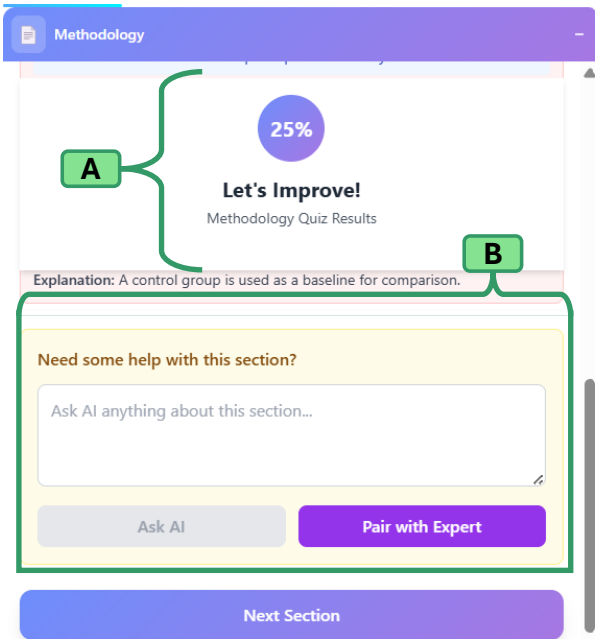

Fig. 3. Quiz results with AI-driven feedback. Users who score poorly receive detailed explanations for incorrect answers, along with the option to seek further AI assistance or pair up with a high-performing peer for clarification.

4 AI-Powered Collaborative Research Flow

Collaborative reading of academic papers often lacks direction and focus without a clear structure. To enhance these sessions, PaperPal introduces an AI-guided research flow that combines structured research phases with time-boxed research sprints. This method ensures the group remains focused, engages deeply with the material, and produces valuable outcomes throughout the process.

The research flow begins with the Understanding Phase, where the group identifies unfamiliar terms or concepts. The AI offers immediate support, providing definitions, examples, and simple explanations to build a shared foundation, making sure everyone is on the same page before delving into more complex material.

Once the group has a common understanding, the focus shifts to a deeper Exploration Phase. Here, participants read and analyze the paper more closely, annotating key points, asking questions, and discussing ideas. The AI monitors these interactions and steps in when it detects confusion or recurring questions, offering clarifications and linking related concepts to help the group stay on track.

After exploring the paper, the AI helps the group transition into the Synthesis Phase. It collects all annotations, comments, and discussions to create a unified summary, organizing the key takeaways and themes that emerged during the group's analysis. This provides a consolidated overview of the collective understanding, helping the group reflect on what they've learned.

To further broaden the group's knowledge, the flow transitions into the Related Work Phase. Based on the key points discussed, the AI recommends relevant papers for further reading. These suggestions support continued exploration and deepen the group's understanding by connecting their work to other scholarly contributions.

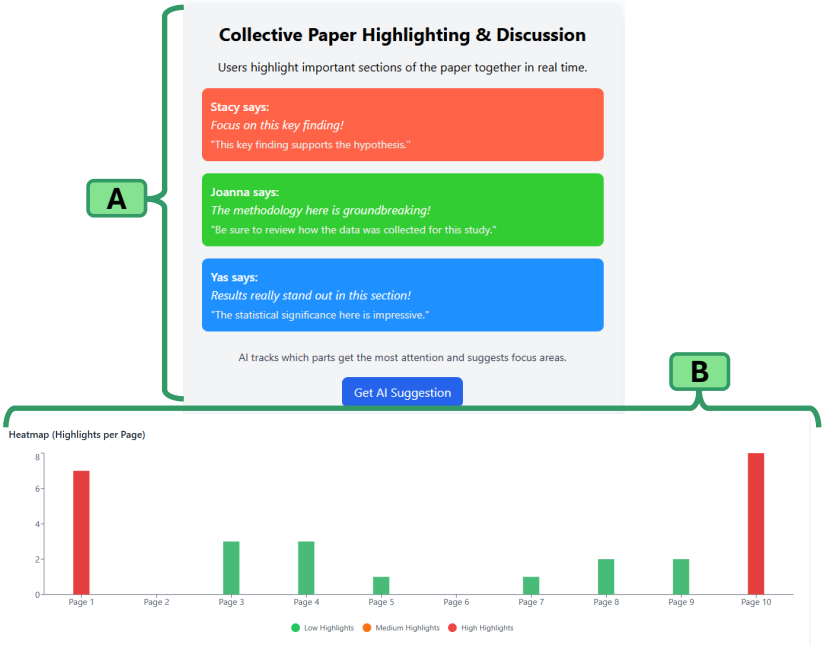

Fig. 4. AI-organized highlights and discussion threads, with a heatmap showing pages that received the most attention. This helps users focus on key discussion points and areas of the paper that need more clarification.

In addition to these structured phases, PaperPal incorporates *research sprints* time-boxed tasks that focus the group's efforts on specific objectives. Each sprint begins with a prompt, guiding the group to activities like summarizing key findings, critiquing the study's methodology, or comparing insights across papers. During these sprints, the group can self-assign roles or receive AI recommendations based on each participant's strengths or previous contributions. This ensures that everyone is engaged and that the work is distributed effectively.

Once the sprint tasks are completed, the AI evaluates the group's submissions, checking for clarity and insight. It then compiles the best contributions into a collaborative report, suggesting revisions where necessary. This results in a well-organized summary of the group's collective work that can be saved, shared, or refined in the future.

4.1 Collective Paper Highlighting & Discussion

One of the key features of PaperPal is its real-time collaborative highlighting system. As users read a paper together, they can highlight sections of text—whether sentences, paragraphs, or figure captions to emphasize important points, pose questions, or mark areas of confusion. These highlights appear instantly for all group members, creating a shared view of the paper that reflects the group's collective focus and interests.

To identify the sections that are receiving the most attention, PaperPal employs an *attention-weighted heuristic* (Fig 4). This method tracks how frequently and recently parts of the paper are highlighted. Sections that attract many highlights in a short period are flagged as important or potentially confusing, helping the AI determine where additional assistance may be needed.

When a user hovers over a highlighted section, the AI assistant offers contextual help, displaying related content either from the current paper or from previous works. This helps users make connections between ideas, enhancing their understanding of the material.

In addition to highlighting, each section marked with a highlight generates a dedicated discussion thread. Users can start or join conversations about specific highlights, promoting focused, in-depth discussions. These threads are organized with markdown formatting to ensure clarity and ease of navigation. The system also tracks the evolution of these discussions, allowing users to review the conversation history. A collapsible sidebar next to the document viewer provides quick access to all active discussion threads, keeping the workspace neat and organized.

By combining real-time highlighting, attention tracking, and embedded discussion threads, PaperPal transforms reading academic papers into an interactive, collaborative learning experience. Each highlight encourages engagement with the material, enabling users to share insights and deepen their collective understanding.

4.2 Personalized Feedback, Engagement Tracking, and Peer Support

PaperPal adapts to each user's behavior by tracking their activity during the reading session. It monitors actions such as annotations, quiz participation, engagement in chat, and interaction with AI-generated content, creating a personalized profile to assess each user's involvement and understanding. If a user becomes inactive or frequently asks for help, the system recognizes this as a potential sign of confusion or fatigue. Rather than interrupting the group, it sends gentle prompts, offering support or suggesting pairing with a more active peer. This approach provides timely assistance without singling anyone out, promoting peer support and strengthening collaboration.

Additionally, PaperPal allows users to provide feedback on AI-generated responses—whether through upvoting, downvoting, or requesting more detailed explanations. This feedback helps the AI tailor future responses based on user preferences. For example, if a user prefers concise answers, the AI will adjust to provide shorter responses by default.

By combining real-time tracking with adaptive AI feedback, PaperPal creates a supportive learning environment that ensures every user receives the personalized help they need to stay engaged and make progress.

5 Limitations and Future Work

While PaperPal introduces several novel features for collaborative academic reading, it has not yet been evaluated through a formal user study. Understanding how users interact with the system in real-world settings is crucial, and we plan to conduct structured user evaluations to assess usability, learning outcomes, and group engagement. Additionally, the current system focuses primarily on synchronous collaboration. Future work will explore asynchronous workflows to support teams operating across different time zones. Another area for development is extending the AI's contextual awareness across multiple papers, enabling deeper cross-document insights and long-term research assistance. These efforts will help us refine PaperPal into a more robust, adaptive platform for collaborative scholarship.

6 Conclusion

PaperPal represents a significant step forward in enhancing collaborative academic reading through AI-powered tools. By integrating features such as real-time highlighting, collaborative annotation, personalized summaries, and targeted support, PaperPal fosters a more interactive and engaging learning environment. The platform actively tracks user engagement and provides contextual assistance, ensuring that all participants, regardless of their background or learning style, are supported throughout the reading process. With its ability to adapt to individual needs and encourage peer support, PaperPal not only facilitates comprehension but also nurtures a sense of collective understanding. As we

continue to refine the platform and expand its capabilities, PaperPal has the potential to transform how academic communities collaborate, learn, and engage with research material, paving the way for more efficient, inclusive, and insightful academic discussions.

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