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

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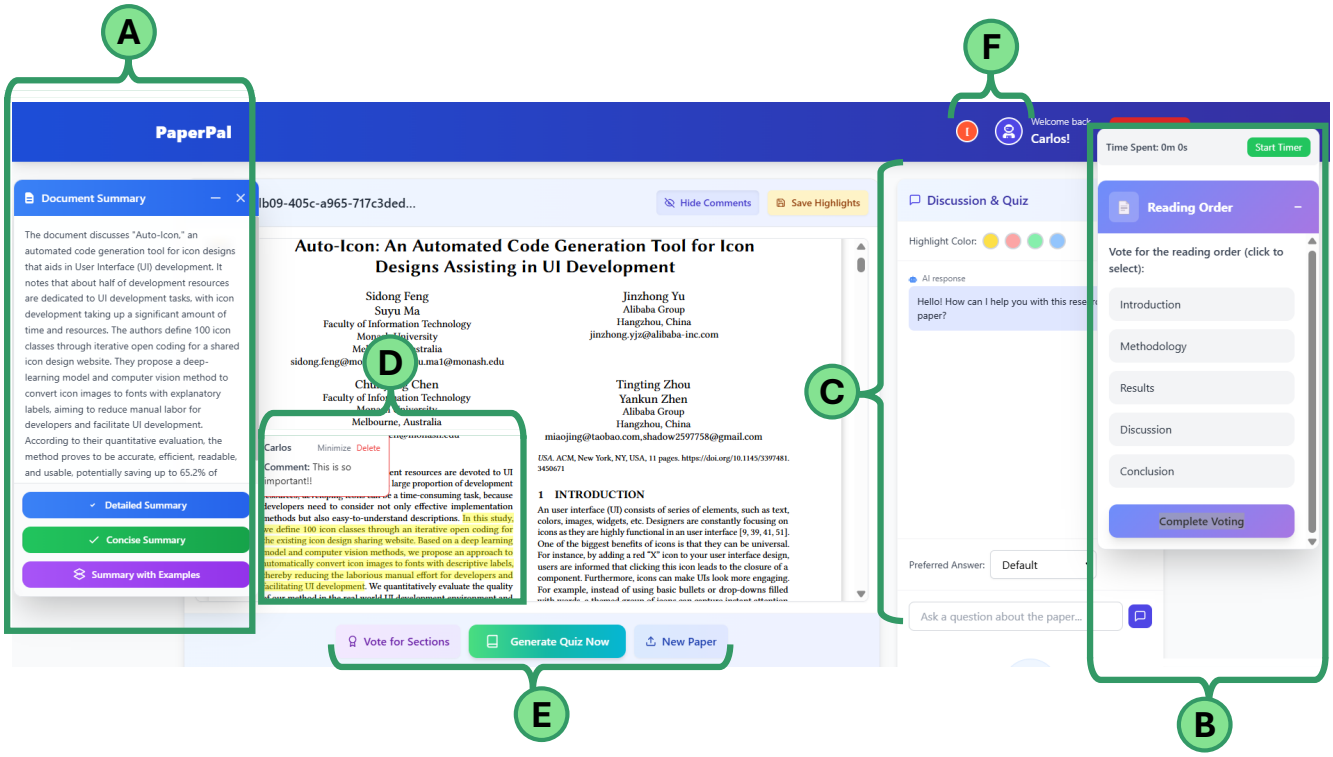

Figure 1: Overview of the PaperPal Interface (A) Dynamic Summary allows you to adjust the detail level in AI-generated summaries for each section of the paper. (B) Voting and Quiz lets you vote for the next section and take quick quizzes. (C) AI Help and Chat provides live chat and immediate AI assistance. (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.

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Abstract

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.

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.

Keywords

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 [16]. However, the process is often held back by practical challenges. The tools commonly used such as 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 [5, 7].

Collaborative reading introduces coordination and communication challenges distinct from individual engagement. Beyond shared document access, it requires maintaining cognitive alignment across participants with varying reading speeds, interpretive approaches, and willingness to contribute. These variations often lead to resynchronization; some users advance too quickly, others fall behind, and discussions risk being dominated by a few voices. Without structured mechanisms for turn-taking, focus maintenance, and mutual awareness, group discussions may drift, stall, or marginalize less vocal participants. Addressing these issues requires not only feature integration, but also intentional design strategies that support real-time collaboration, equitable participation, and collective comprehension.

Recent progress in generative AI, especially large language models (LLMs) like GPT-4,[1] offers new ways to support these group experiences. LLMs can explain complex ideas, summarize content, track engagement, and detect confusion to provide timely, adaptive help. However, current systems still have important limitations. EduChat [5] structures group discussion with prompts, but may limit quieter voices. MAI Flow [7] uses rules to detect confusion but lacks deep personalization. Mibi [8] focuses on emotional wellbeing rather than academic understanding. Co-Pilot [9] allows teachers to design their own AI agents, but depends heavily on user-authored logic, which can lead to inconsistent results. Overall, these are useful tools used everyday by researchers, however they are currently used separately, across different platforms and interfaces which can limit the workflow and communication of a team.

We introduce PaperPal, an AI-powered platform for collaborative academic reading. It brings real-time highlighting, shared annotations, AI-generated summaries, comprehension checks, and embedded chat into a single environment. As students engage with papers, the AI monitors reading behavior, such as pauses, annotations, and discussion activity, to offer context-aware help. It can clarify difficult sections, give examples, or summarize key points. Readers can vote on which section to read next, choose between summary depths, and take quick quizzes to check understanding. Based on their interactions, the system offers targeted support and can even encourage stronger readers to help their peers. By combining generative AI with structured group tools, PaperPal makes reading more focused, collaborative, and inclusive. Figure 1 shows an overview of the platform's core features.

2 Background and Literature Review

Most AI-based reading tools are designed for individuals, not groups. Even as large language models (LLMs) like ChatGPT become common in education, their design often assumes a single user working alone. Seymour et al. [13] highlight how this one-user, one-device approach dominates current conversational interfaces, making them poorly suited for collaborative learning environments. However, academic reading, especially in higher education and research is often social, where collaboration, peer support, and conversational engagement play a central role in comprehension and participation [1, 3, 4]. Students read papers together, share interpretations, clarify confusion, and learn through discussion. Supporting this kind of group-based reading requires tools that help learners coordinate, stay engaged, and build shared understanding, challenges that solo-oriented systems are not designed to address.

Several existing systems attempt to facilitate collaborative learning; however, their approaches often lack the adaptability and contextual depth required for complex, co-located or distributed academic tasks. EduChat [5], for example, uses LLMs to guide group conversations using scripted prompts aligned with the ICAP framework. While effective in structured classroom discussions, it lacks flexibility for informal peer-driven study sessions or asynchronous group reading. MAI Flow [7] detects signs of disagreement or confusion in collaborative chats and introduces steering questions, but it often generates generic responses that are not deeply tailored to the group's context. VizGroup [15] tracks participation patterns in coding classrooms through visual analytics, but its focus is on

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

instructor awareness rather than improving students' shared comprehension during reading. These systems bring valuable insights into group dynamics, but they were not designed to support small, self-managed groups engaging with dense academic texts where meaning must be co-constructed, not merely facilitated.

Other tools focus more on individual learning. AgentCF [17] recommends resources by modeling learner preferences and behaviors, but its recommendations can miss the mark when learner goals or comprehension levels shift. Coaching Copilot [2] supports leadership development through a blend of AI feedback and human mentorship, yet relies heavily on expert oversight, making it less accessible for everyday learners. Solve-then-refine systems [11] encourage students to try solving problems before consulting AI support, but often assume learners can evaluate when to seek help. Even learnersourcing platforms [14], which use AI to generate and deliver peer feedback, raise concerns around inconsistent feedback quality and the risk of learners becoming overly dependent on the AI. These systems focus on autonomy, but typically treat collaboration as out-of-scope or secondary.

A major risk in many AI-powered learning systems, especially those using LLMs is the issue of hallucination: confident but inaccurate responses. These hallucinations can undermine the reliability of educational tools, leading to the dissemination of misinformation and eroding user trust [10]. This risk is magnified in collaborative contexts where misinformation can easily ripple through a group. De Jong et al. [6] show that even after encountering false information from an AI, users often continue relying on its suggestions, sometimes questioning their own judgment. Similarly, in healthcare domains, users have been found to overtrust conversational agents despite inconsistent or unsupported responses [12]. To reduce this risk, our system applies Retrieval-Augmented Generation (RAG) to ground AI outputs in the actual content of the uploaded paper. However, factual grounding alone is not enough. Supporting group comprehension also means helping learners recognize when to challenge the AI, question assumptions, and clarify points with peers. This calls for design strategies that go beyond content delivery toward collaborative sensemaking.

In addressing the limitations of existing tools, PaperPal embeds a conversational interface directly into the collaborative reading workflow, treating it as a central mechanism rather than a peripheral chatbot. This AI assistant engages in context-aware dialogue, offering layered explanations that respond dynamically to section-specific queries and group-level discourse. Rather than waiting for prompts, it acts as a continuous, intelligent guide throughout the reading process.

To support its embedded conversational framework, PaperPal employs structured interaction mechanisms that facilitate synchronized comprehension and the co-construction of knowledge among users. Collaborative annotation allows users to highlight and comment directly on the text, surfacing individual interpretations within shared context. Tunable AI-generated summaries provide adjustable levels of abstraction, enabling readers to tailor informational depth to their comprehension needs. Section voting supports coordinated navigation by enabling the group to prioritize reading order democratically. Engagement monitoring tracks participation patterns and introduces unobtrusive prompts to mitigate disengagement. Collectively, these features scaffold equitable interaction, promote mutual awareness, and support the transition from parallel reading to the co-construction of understanding.

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.

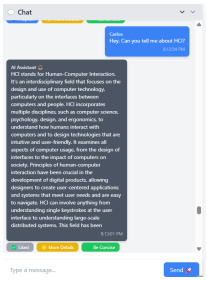

Figure 2: Central hub for discussion. Users engage in real-time conversation alongside the paper, with the AI assistant offering context-aware responses based on the current section. It provides clarifications, summaries, and prompts to support the flow of dialogue and encourage balanced participation.

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.

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

[2] https://react-pdf-viewer.dev/
[3] https://pdf-lib.js.org/

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). Rather than being an auxiliary feature, the chat serves as the central collaborative space where annotation, summarization, comprehension checks, and AI support converge. By embedding conversation directly beside the document, PaperPal turns dialogue into a core part of the reading experience.

The chat system is powered by Firebase, which ensures real-time message delivery, facilitating continuous and uninterrupted collaboration. As users read and annotate, they can seamlessly switch to discussing content with peers. The chat features an embedded AI assistant, powered by GPT-4, which participates as a context-aware group member, not as a separate chatbot. It responds based on the current section of the paper and the ongoing dialogue. For example, asking "Can you explain the methodology section?" will prompt the AI to give a focused response aligned with that exact passage. To support inclusive and balanced conversation, the AI monitors turn-taking dynamics and only intervenes when clarification is needed or when the conversation stalls, helping maintain a healthy rhythm of dialogue.

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 enables the assistant to adapt over time to better suit the group's needs. To support engagement, the system gently monitors participation and sends private, respectful reminders to inactive users, such as "Would you like to share your thoughts?" or "Let me know if anything is unclear."

All chat messages, including AI responses and user feedback, are saved with timestamps and usernames. Messages support markdown formatting and can be linked directly to highlights in the paper, maintaining clarity and contextual relevance. By making the chat the connective layer across the entire workflow, PaperPal fosters a dynamic, shared space for collaborative understanding.

3.3 Tunable AI Summarization

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.

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

3.4 Guided Reading with Section Voting & Comprehension Questions

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.

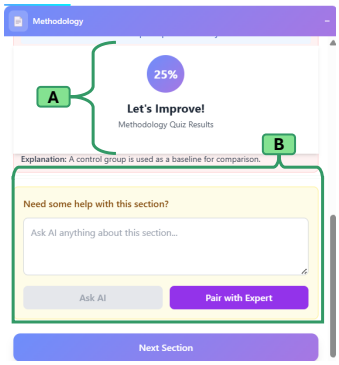

Figure 3: Quiz results with AI-driven feedback. Users who score poorly receive detailed explanations for incorrect answers, along with the option to seek further AI assistance or pair up with a high-performing peer for clarification.

If a user scores poorly, the system offers personalized support by providing simplified explanations, clarifications, and suggestions to revisit the relevant parts of the paper (Fig. 3.A). Additionally, users can receive assistance from the AI assistant or be paired with a high-performing peer to collaborate, discuss concepts, and improve understanding. Throughout the quiz process, the chat remains open, allowing peers to discuss tricky questions or clarify confusing answers with each other or with the AI assistant (Fig. 3.B).

4 AI-Powered Collaborative Learning 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

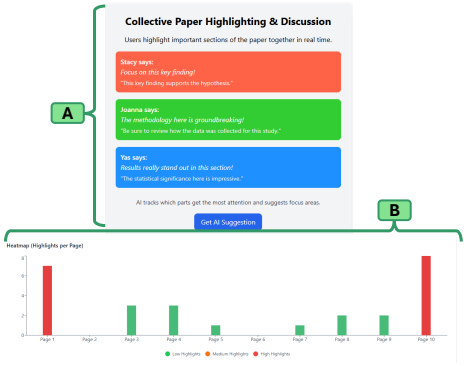

Figure 4: AI-organized highlights and discussion threads, with a heatmap showing pages that received the most attention. This helps users focus on key discussion points and areas of the paper that need more clarification.

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 have 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.

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. The main group chat also stays active during annotation, giving users a shared space to ask questions, reflect on highlights, or request AI clarification without leaving the document view. 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

Although PaperPal incorporates several innovative features to support collaborative reading, it has not been subjected to evaluation through a formal user study as of this moment. To understand PaperPal's effectiveness in real-world settings, we plan to conduct structured evaluations including task-based usability studies, comprehension assessments to measure learning gains, and observation of group interactions to evaluate participation balance, coordination, and collaborative knowledge construction. The current implementation supports synchronous collaboration, but future versions will expand to include asynchronous workflows that better support distributed teams. We also plan to enhance accessibility features such as screen reader compatibility, scalable text, and full keyboard operability.

As with any system powered by large language models (LLMs), PaperPal presents certain risks. Despite using Retrieval-Augmented Generation (RAG) to ground responses in the uploaded paper, hallucinations, plausible but incorrect outputs can still arise and potentially mislead users during group discussion. To mitigate this, we plan to enhance transparency through clearer uncertainty cues, user-driven clarification prompts, and refined feedback loops. Although the system does not retain uploaded documents, it logs user interactions such as highlights, comments, and quiz results to improve learning insights.

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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