DEVELOPMENT OF AN AI-ASSISTED DIGITAL PLATFORM FOR PERSONALIZED LEARNING IN A COMPETENCY-BASED TEACHING AND ASSESSMENT CONTEXT

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Abstract. *In the face of modern educational challenges such as information overload and a scarcity of accessible digital tools for students with impairments, this project introduces an innovative solution. We have developed an AI-powered personal study assistant website designed to enhance learning through AI-driven summaries, personalized quizzes, and comprehensive progress tracking. The platform was built using a modern technology stack including TypeScript, React, and Tailwind for the frontend, with MongoDB Atlas serving as the backend database. Its core intelligence is powered by the Gemini Large Language Model API, which is prompted to source information from academic materials like Google Scholar, didactic books, and university resources, with outputs structured via JSON for translation and display. Accessibility is a cornerstone of the project, achieved by adhering to WCAG standards and integrating the UserWay API. The result is a fully functional, user-friendly platform with a polished interface, featuring robust accessibility tools, personalized digital notebooks, and a variety of performance graphs to visualize learning progress. This work demonstrates a successful fusion of AI and user-centered design to create a more effective and inclusive educational experience.*

Keywords. *Personal Study Assistant. E-Learning. Personalized Learning Context.*

Introduction

Higher education is going through a major transformation driven by fast technological change and new professional demands. Current curricula increasingly focus on developing both cognitive and interpersonal competencies, guided by competency-based learning frameworks adopted by universities worldwide (van Berkum et al., 2024; Todaro & Lebrão, 2022; Ferraz & Belhot, 2010). In line with this view, Higher Education Institutions (HEIs) are adopting teaching strategies that foster evidence-based learning, continuous assessment, and the integrated development of knowledge, skills, and attitudes.

Developing these competencies is especially important in today's knowledge-driven world, where students are expected not only to gather information but also to analyze, interpret and create solutions to real and socially relevant problems. Yet, while digital transformation has made information more accessible, it has also brought new challenges. Students now face an overwhelming amount of online content, often mixed with unreliable sources, fragmented data, and misinformation. Studies show that such information overload can harm memory retention, lower motivation, and limit the development of higher-order thinking skills (Tafesse et al., 2024).

In addition, the rapid spread of generative artificial intelligence adds another challenge: many students use AI tools to obtain instant answers instead of building genuine understanding, which reinforces shallow learning habits. Researchers have highlighted the urgent need for personalized learning paths aligned with competency development (Loitsch et al., 2024; Nakao et al., 2012). When structured according to models like the Revised Bloom's Taxonomy, digital platforms can guide learners through levels of cognitive complexity, from remembering and understanding to recognizing and creating, helping them develop skills progressively and measurably. Likewise, competency-based assessment models suggest combining diagnostic, formative, and summative tools to monitor progress, provide feedback, and support instructional decisions (Kalnina et al., 2024; Todaro & Lebrão, 2024).

From this perspective, artificial intelligence, when used ethically and pedagogically, can serve as a supportive tool that promotes active learning, critical thinking, and inclusion. In response to these challenges, this work presents Smart Study, an AI-powered personal study assistant designed to foster competency-based learning, deep understanding, and accessibility. The platform combines the structure of Bloom's Revised Taxonomy with personalized feedback and multimodal accessibility features that support visually impaired, deaf, and ADHD users (Song, Wang & Zhang, 2024). Crucially, this initiative directly addresses one of the 14 Grand Challenges for Engineering identified by the National Academy of Engineering (NAE): to "Advance Personalized Learning." By leveraging technology to tailor instruction to individual needs, the project aligns with the global engineering goal of making education more effective and inclusive.

By integrating generative AI with a solid educational framework, Smart Study aims to reduce information overload, discourage surface-level learning, and ensure equitable access to high-quality learning experiences. In this context, the aim of this work is to develop and test the preliminary version of the Smart Study platform as a practical solution that promotes meaningful learning through personalized study experiences. It is worth noting that this work represents part of a broader research effort currently being developed within the GCSP-IMT Program.

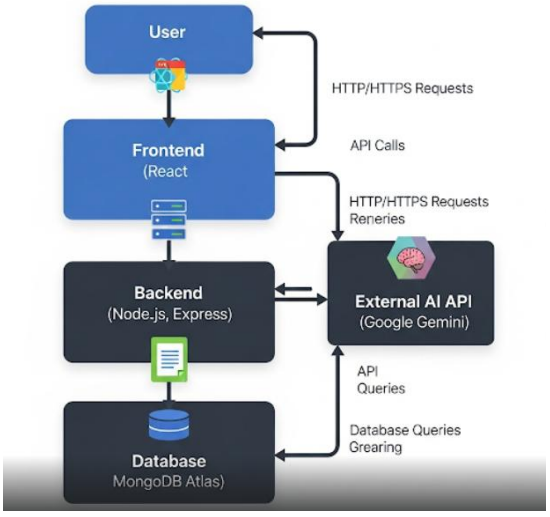
Methodology

The research adopted a design-based approach, combining pedagogical theory with user-centered design principles to ensure the system met both educational and technical requirements. The development process followed an iterative lifecycle aimed at solving the specific problem of creating an inclusive, competency-based learning environment. The functional and non-functional requirements were defined based on the Universal Design for Learning (UDL) framework (Mayer, Rose & Gordon, 2014). To address the requirement of supporting diverse cognitive profiles, the design strategy prioritized the reduction of perceptual barriers. Consequently, the World Wide Web Consortium (W3C) (2023) accessibility standards (WCAG 2.2) were adopted not merely as a checklist, but as a foundational architectural constraint. This methodological choice dictated the implementation of specific features such as high-contrast modes, dynamic font resizing, and the suppression of non-essential animations to minimize cognitive load.

To translate these requirements into a functional system, a modern full-stack architecture was selected to ensure scalability and maintainability. A component-based architecture using React was chosen for the frontend to manage the complex state of personalized interactions, allowing for the creation of reusable, accessible UI primitives that enforce consistency across the application. On the server side, a Node.js and express environment coupled with MongoDB Atlas was implemented to handle unstructured data, such as variable-length personalized summaries and JSON-based quiz outputs, efficiently. The choice of a NoSQL database specifically addressed the need for flexible data modeling of user progress and "Notebook" structures. Furthermore, the methodology for integrating the Gemini LLM involved prompt engineering focused on strictly structured JSON outputs. This method was chosen to prevent "hallucinations" in formatting and to ensure that the content could be programmatically parsed and rendered into the accessible UI components defined in the frontend phase.

Finally, the project methodology clearly distinguished between student assessment (pedagogical) and system evaluation (technical). In terms of pedagogical assessment logic, the system was programmed to support formative assessment where quizzes were designed not just to grade, but to provide feedback loops with corrective explanations based on Bloom's Taxonomy, reinforcing the "Understand" and "Apply" levels. Regarding the system protocol, technical validation was conducted using quantitative audits via Google Lighthouse to measure adherence to the defined accessibility and performance requirements. Additionally, usability testing involved iterative cycles where interface refinements were made based on user interaction with the accessibility modes.

Figure 1 – Smart Study´s software architecture representation.



Additionally, it is important to highlight that the platform operates on a robust client–server architecture. The frontend, implemented as a React-based Single Page Application (SPA), manages interface rendering and client-side state while communicating with the backend through a stateless RESTful API. The backend, developed with Node.js and Express, handles all business logic, authentication, data

persistence, and integration with Google's Generative AI services. The system operations follow a structured data flow: users interact with the frontend, which sends authenticated HTTP requests to the backend; middleware validates credentials, controllers orchestrate services, services interact with MongoDB Atlas via Mongoose models and external AI endpoints, and responses are returned to update the user interface.

In a complementary way, the backend subsystem is modular and implemented in TypeScript, with clear separation of concerns through routes, controllers, services, models, and middleware. Data modeling employs Mongoose schemas for Users, Notebooks, Topics, and Attempts, enforcing structure and relationships. Security is ensured by a stateless authentication mechanism using JWTs, validated on protected endpoints via middleware. After prompt construction, the backend sends the request to the Gemini API, parses the returned JSON, and forwards the structured quiz data to the frontend. The interface then dynamically renders the QuizRunner component using iterative mapping functions.

The frontend architecture follows a hierarchical component model composed of reusable UI primitives, feature components, and page-level views. Local state is handled through standard React hooks, while global application state (such as authentication and accessibility settings) is managed via the Context API. API requests are centralized through a configured Axios instance equipped with JWT injection interceptors.

Finally, accessibility is integrated throughout the component architecture through semantic HTML and ARIA-compliant roles provided by Radix UI, ensuring compatibility with assistive technologies. Keyboard navigation is fully supported through controlled focus management, and additional user customization is enabled via the UserWay API (2025), allowing adjustments to contrast, spacing, font preferences, and animation settings beyond baseline WCAG requirements.

Results and Discussion

Digital learning environment setup

The implemented environment incorporates multiple accessibility mechanisms aligned with the aims of reducing perceptual barriers and cognitive overload. Upon authentication, users access a unified home interface equipped with a persistent navigation bar and an integrated accessibility control. Features include high-contrast color inversion, dynamic text resizing for improved legibility, and a Focus Mode that suppresses non-essential visual elements, supporting learners with attention-related difficulties.

To accommodate diverse cognitive profiles, visual elements such as animations and complex imagery can be disabled, while adjustable color schemes provide additional comfort to users with visual sensitivity. The interface also offers multilingual support, allowing seamless transition between English and Brazilian Portuguese, alongside a sign-language widget for deaf users. When accessibility features are activated, the system retains these preferences and provides persistent, one-click access to pages optimized for screen readers and assisted navigation technologies. In terms of information architecture, a hierarchical organization was implemented to facilitate retrieval and contextualization. The notebook management page enables content creation, editing, and deletion, promoting autonomy while maintaining structural clarity. Iterative prototype evaluations

resulted in layout refinements that prioritized simplicity, contrast, and intuitive navigation, enhancing usability for students with ADHD or visual impairments. Collectively, these results demonstrate the platform's effectiveness in delivering an inclusive, customizable learning experience.

Figure 2 illustrates the home screen, which displays the platform's central interface and provides quick access to core features through a persistent navigation bar and an accessibility panel. From this screen, users can enable options such as high-contrast mode, text resizing, and Focus Mode, which hides non-essential visual elements. These configurations enhance visual comfort, reduce cognitive load, and promote an inclusive and customizable study experience.

Figure 2 – Smart Study´s homepage and its content.

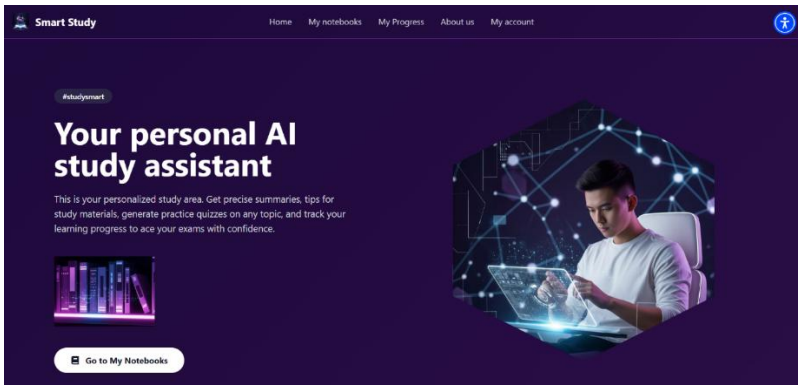


Figure 3 depicts the notebook management screen, functioning as the main area for organizing study content in a two-level hierarchical structure. From this interface, users can create notebooks for broader subjects and add classes for specific topics, with options to create, edit, or delete content. Each class provides interactive access to its dedicated study environment, supporting clear organization and intuitive navigation.

Figure 3 – Smart Study´s "my notebooks" page and its content.

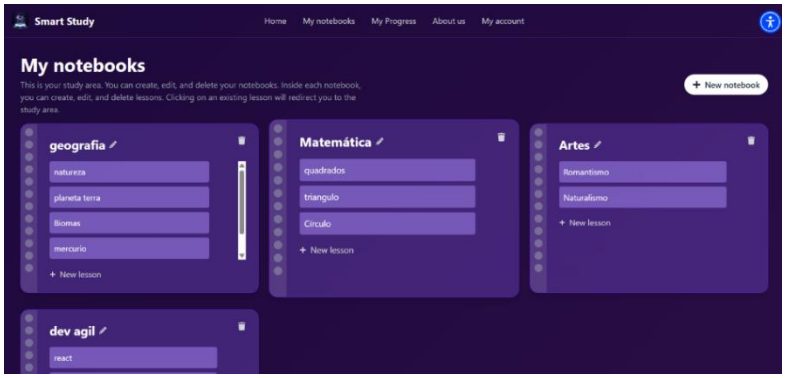


Figure 4 presents the summary screen, which displays the platform's AI-powered conversational interface. In this space, users can submit a topic and receive a structured summary with subheadings and suggested external resources. The generated content can

be saved to personal notes, and users may continue the interaction to request additional topics, maintaining autonomy over their learning process.

Figure 4 – Smart Study´s "summary" page and its content.

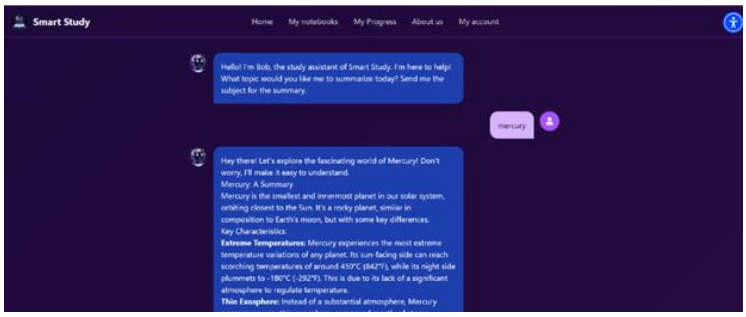


Figure 5 demonstrates the quiz screen, which features the platform's interactive assessment function. Users receive automatically generated multiple-choice questions based on a selected topic, and each response triggers instant visual feedback followed by an AI-generated explanation to reinforce understanding. At the end of the quiz, a performance summary is displayed, and results can be saved to the user's progress history. Complementarily, Figure 6 portrays the progress screen, which displays interactive visualizations of average scores by subject, lesson, and individual attempt. These analytics help students identify strengths, target areas for improvement, and monitor performance trends over time. Flexible viewing options allow learners to personalize their analysis and adjust study strategies based on data-driven insights.

Figure 5 – Smart Study´s "quiz page" example.

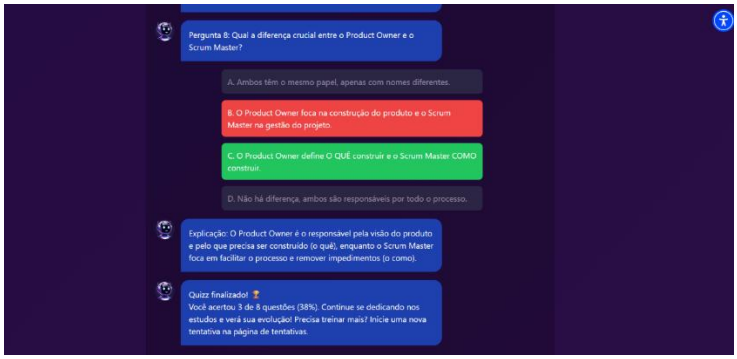
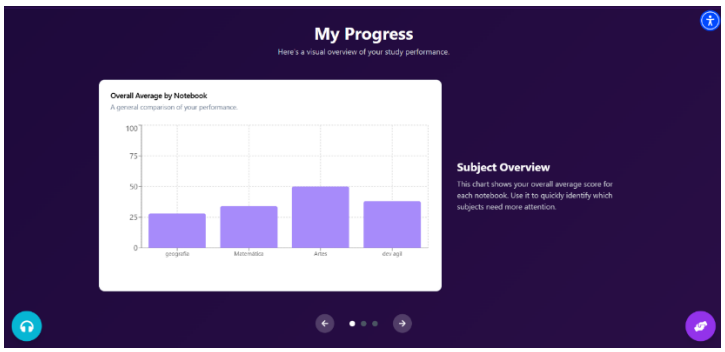


Figure 6 – Smart Study´s "my progress" page and its content.



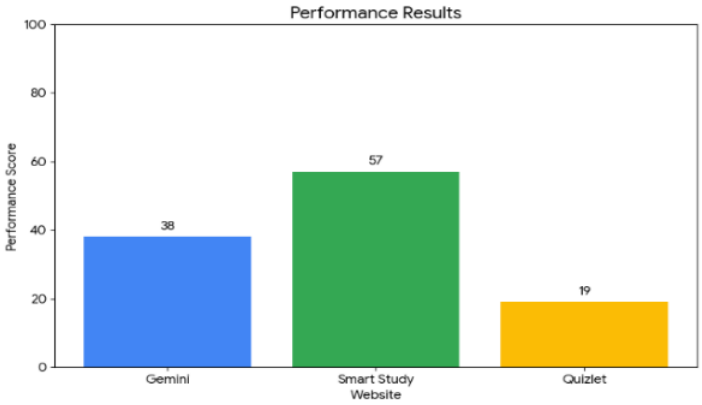
Preliminary tests with Smart Study platform as a personalized learning solution

The platform integrates generative AI features that support personalized study workflows aligned with the lower levels of Bloom's Revised Taxonomy: remember, understand, and apply. Its conversational summarization tool generates structured explanations with clearly defined subtopics and relevant external resources, enabling learners to consolidate understanding and broaden their study scope. These summaries can be saved as personal notes, allowing students to revisit and refine their learning materials over time.

The quiz interface reinforces active recall by presenting automatically generated multiple-choice questions with immediate visual feedback and explanatory corrections, strengthening conceptual comprehension. After completing each attempt, students receive a detailed performance summary and can retake quizzes to monitor their progress and reinforce weaker areas. A dedicated analytics page provides interactive visualizations displaying average scores by subject, lesson, and attempt. These dashboards reveal learning trends, highlight specific gaps, and support strategic decision-making, empowering learners to adjust study habits based on data-driven insights. Testing phases focused on usability, clarity of feedback, effectiveness of accessibility modes, and improvement across repeated attempts. The insights obtained led to refinements in interface simplicity, visual hierarchy, and AI response coherence, which collectively enhanced both usability and perceived pedagogical value.

Finally, a quantitative technical audit conducted with Google Lighthouse demonstrated positive results. As can be seen in Figure 7, the platform achieved an accessibility score of 92, surpassing reference systems such as Quizlet and confirming adherence to inclusive design standards. Its performance score of 57, considerably higher than comparable AI-enabled tools, indicates optimized frontend execution and efficient data handling despite the system's computational complexity. These outcomes validate the architectural strategy adopted, showing that Smart Study successfully balances performance, personalization, and accessibility within a cohesive pedagogical framework.

Figure 7 – Gemini vs Smart Study vs Quizlet performance comparation results chart.



Building upon these results, the next stage of development will focus on customizing the learning environment to support competency-based assessments. This enhancement will allow the platform to integrate seamlessly with instructor-defined learning references, enabling the creation of adaptive tests aligned with specific course outcomes and competency frameworks. Through this advancement, Smart Study will evolve from a personalized study tool into a comprehensive environment capable of supporting evidence-based learning and instructional alignment.

Conclusion

The development of the Smart Study platform represents a preliminary integration of artificial intelligence, accessibility engineering, and pedagogical design within a unified digital learning environment. By aligning generative AI functionalities with Bloom's Revised Taxonomy and the Universal Design for Learning framework, the system effectively supports diverse cognitive and accessibility needs. The implemented tools, such as AI-generated summaries, quizzes with explanatory feedback, and dynamic performance analytics, demonstrate the platform's capacity to promote personalized learning experiences.

The achieved results validate the methodological coherence and technical robustness of the system. The quantitative audit using Google Lighthouse confirmed high accessibility and performance standards, while usability tests evidenced the platform's effectiveness in enhancing engagement and comprehension among different learner profiles. Collectively, these findings confirm that Smart Study succeeds in translating pedagogical theory into a functional, inclusive, and adaptable educational technology.

The continuity of the present work will focus on advancing the platform's personalization engine to enable competency-based assessments integrated with instructor-defined learning references. This enhancement will allow educators to design adaptive assessments aligned with specific curricular outcomes and competency frameworks, extending Smart Study's potential as a comprehensive, evidence-driven learning environment. Through this next phase, the project aims to consolidate its contribution to inclusive and competency-oriented environment.

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