Brainy: An Innovative Context-Aware Generative AI Engine for Education

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Abstract
In the realm of education, the integration of Generative AI tools within learning platforms has transformed teaching and learning paradigms. This paper introduces Brainy, a context-aware AI engine integrated into the Augmental Adaptive Learning platform, which implements the concept of Differentiated Instruction. At its core, Brainy employs Generative AI Models, leveraging a variety of Language Learning Models (LLMs), including OpenAI. This integration enables Brainy to generate personalized course materials and assessments tailored to individual learner needs, in addition to offering multiple learning paths. By considering learning objectives, prior knowledge, and learner proficiency levels, Brainy ensures an adaptive learning experience that promotes equity in education. It refines content and learning activities, adjusts to accommodate each learner's learning style and progression and offers feedback on assessments using a supportive educational approach, including clear explanations and analogies that address individual learning needs. This integration not only elevates the learning experience for learners but also empowers Instructors to have complete control to review the AI-generated content, ensuring an alignment with educational goals and principles and a balance between personalization and standardization, essential to maintain integrity and effectiveness of the educational process. In summary, Brainy offers differentiation in terms of content, process, and result assessment, tailoring content to individual learner needs, adapting the learning process to diverse learning styles, and providing personalized feedback that enhances the learning experience for all learners. The implementation results confirm Brainy's personalized learning approach. However, experiments and data analysis are in perspective to better understand the solution's performance in terms of efficacy and accuracy. This involves conducting a more in-depth assessment to evaluate the impact of the solution on learners' learning outcomes.

Keywords: Adaptive Learning, Differentiated Instruction, Personalized Learning, Context-Aware Generative AI

Introduction

Differentiated Instruction (DI), the pedagogical approach that recognizes and supports the diverse learning needs of learners, has long been valued for its ability to enhance learners' engagement, motivation, and learning outcomes. One of the key benefits of DI is its ability to cater to individual learner needs, allowing each learner to learn at their own pace and in a manner that aligns with their unique learning style. This personalized approach has been shown to improve learner achievement and overall academic performance (Tomlinson, 2017). However, implementing DI in a traditional classroom can be challenging for instructors, as it requires creating and managing multiple lesson plans and learning activities to accommodate diverse learner needs. Additionally, providing timely and meaningful feedback to learners can be difficult, especially when learners are working at different levels or on different tasks.

By leveraging AI and other technologies, these challenges can be mitigated. In this paper, we present Brainy, an AI-powered solution, embedded within Augmental Adaptive Learning platform, that acts as a context-aware engine. It personalizes content and learning experiences while implementing core DI components such as differentiation in terms of content, process, and result assessment.

Brainy's architecture includes the data layer, generative AI engine, learning platform, and evaluation layer, ensuring a comprehensive implementation of DI principles. It provides multiple learning paths, diverse and personalized content, and assists instructors in monitoring learner engagement. Additionally, Brainy offers constructive feedback tailored to individual needs. This introduction sets the stage for exploring AI's transformative impact on DI and educational outcomes.

Background

This section emphasizes the significance of Differentiated Instruction (DI) and its evolution in pedagogy, particularly its integration into digital platforms. This integration offers broader support and strategies to enhance the effectiveness of DI, addressing challenges related to content diversity, instructional processes, and the assessment of learning outcomes.

The study of Lavania and Nor (2020) presents the challenges instructors face in implementing differentiated instruction (DI) in the classroom. One key barrier identified is the lack of DI knowledge among instructors, hindering their ability to customize instruction effectively for diverse student needs. This knowledge gap can limit the instructor's capacity to provide tailored learning experiences. Furthermore, time constraints pose a significant obstacle to DI implementation, restricting instructors' ability to adequately differentiate instruction to meet individual learner requirements.

The limited time available for lesson planning and delivery can impede the implementation of DI strategies effectively. These two essential constraints make the implementation of differentiated instruction challenging, potentially limiting its effectiveness in meeting the diverse needs of students.

In the same context, the study presented by Ginja and Chen (2020) explores instructors' perspectives and experiences toward Differentiated Instruction in the context of higher education. The findings indicate that a significant number of instructors have a limited understanding of DI and rarely differentiate for students. However, there is a positive outlook on the impact of DI on students' readiness, interests, and learning profiles. Challenges identified include the time-consuming nature of DI, lack of trained instructors, and limited access to professional development on DI topics. Research consistently emphasizes the significance of differentiated instruction (DI) in effectively addressing students' diverse needs by tailoring content and teaching strategies to individual learning styles. Despite its benefits, implementing DI can pose challenges, particularly in developing appropriate content and monitoring student progress to meet their specific requirements.

Recent studies have explored the integration of technology with DI, showcasing how digital platforms can offer more flexible and adaptive implementations. These studies highlight the potential of technology to enhance DI by providing personalized learning experiences and facilitating the tracking of student advancement. By leveraging technology, instructors can overcome logistical hurdles associated with DI, such as creating and delivering varied instructional materials.

In this context, Tahiri, Bennani and Khalidi Idrissi (2017) addresses learner diversity and enhancing educational cooperation in Massive Open Online Courses (MOOCs). The problem statement revolves around the low success rates in MOOCs worldwide, attributed to learners' diversity and discord in educational approaches. The proposed method involves the implementation of a system of differentiated learning paths within MOOCs. The proposed system creates multiple learning paths and ensures all learners have the necessary skills and knowledge to reduce dropout. A key emphasis is placed on using a decision tree approach for clustering learners into homogeneous groups based on predefined rules and objectives. While the method creates multiple learning paths leading to the same objectives, it does not recommend altering or adapting the content. Instead, it emphasizes the process, focusing on the way the learning experience is structured according to students' needs. This approach highlights the importance of customizing the learning process for diverse student needs, ensuring a more engaging and effective educational experience.

Another study explores the use of AI tools in designing MOOC courses, focusing on content creation, interactive learning activities, and student learning outcomes (Morales-Chan, Amado-Salvatierra, & Hernández-Rizzardin, 2023). The authors found that incorporating AI-based tools improved course design quality and effectiveness, reducing time and effort. Tools like ChatGPT and DALL-E 2 were particularly effective in analyzing content, identifying learning objectives, and designing interactive activities. This study introduces an innovative approach to course design, representing a significant paradigm shift. It integrates and leverages AI tools to enhance the efficiency of course design, addressing challenges such as the variety of resources and content for each learner, outcome assessment, and personalized, adapted feedback.

Brainy's Global Architecture

This section presents Brainy, the context-aware engine designed to personalize content and learning experiences. Brainy is integrated into the Augmental Adaptive Learning platform (Augmental, 2024). In Augmental, student initial knowledge is assessed and an adapted learning path is suggested in alignment with his abilities and needs. Initially, implementing Differentiated Instruction in Augmental focused solely on offering multiple learning paths. However, differentiating content remained challenging until the development and implementation of Brainy. Brainy, based on generative AI tools, successfully provides diverse content, tailored evaluation methods, and assists instructors in monitoring the engagement of students and in providing constructive and adapted feedback. Therefore, the global architecture is composed of four main components such as the data layer, the generative AI engine, the learning platform, and the evaluation layer, which is the implementation of the Differentiated Instruction in terms of content, process, and outcome assessment.

Architecture

The Brainy architecture comprises several key layers that work in harmony to an adaptive and context-aware learning experience. The Data Layer forms the foundation, housing essential information such as learning outcomes, lesson plans, and learner data. It evolves continuously, staying updated with the latest insights to ensure Brainy generates accurate and relevant content.

At the core, the Generative AI Model creatively utilizes deep learning techniques, producing context-aware content that adapts to user needs. It simplifies content creation by eliminating the need for complex prompts. The Learning Platform Layer acts as a user-friendly bridge, providing an intuitive interface for seamless interaction with Brainy.

Finally, the Evaluation Layer gathers feedback and iterates on content, enhancing Brainy's proficiency. This multi-layered approach places the power of context-aware generative AI in educators' and learners' hands, revolutionizing the education landscape.

Below are the figures of Brainy's logic model for both instructors illustrated in Figure 1 and learners illustrated in Figure 2.

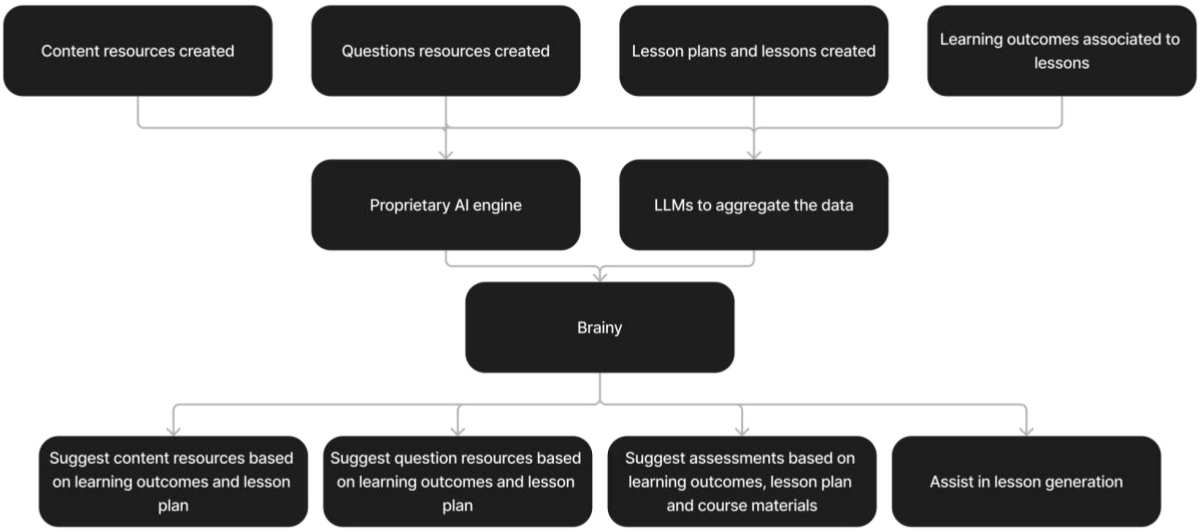


Figure 1: Brainy's logic model for instructors

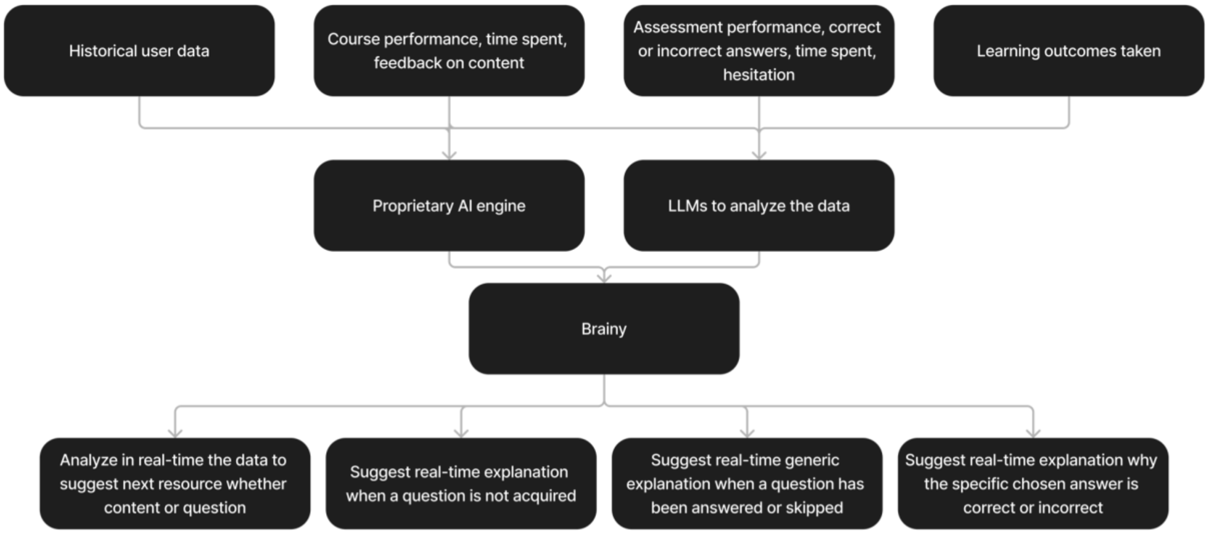


Figure 2: Brainy's logic model for learners

Data Layer

The data layer is the foundation of the Brainy architecture. Within this layer, Brainy stores relevant and useful data including:

- For instructors (Figure 1):The data layer includes the educational materials and question sets they have developed, the structured outlines for teaching (lesson plans), the instructional sessions delivered (lessons), and the educational goals these activities are designed to meet.
- For learners (Figure 2): The data layer contains a record of the learners' historical interactions, their performance in courses, the duration of engagement with educational materials and questions, their feedback on the content, outcomes of assessments, hesitation on questions , as well as the learning goals and objectives they are tackling.

The data layer serves as a constantly evolving repository that is consistently refreshed with the latest educational insights and information. This continuous update process ensures that Brainy is always equipped with the most up-to-date knowledge, enabling it to diagnose the initial knowledge of the learner and to generate content that is not only accurate but also relevant to the specific needs and preferences of instructors and learners. This dynamic nature ensures that Brainy remains at the forefront of delivering cutting-edge educational experiences.

Generative AI Model

At the core of Brainy's architecture lies a crucial layer strategically positioned between the Data layer and the Learning platform, which is the Generative AI layer represented by the "Proprietary AI engine", "LLMs to analyze the data" and "Brainy" in both Figure 1 and 2 . This layer employs advanced generative algorithms to deep learning techniques such as GPT (Generative Pre-trained Transformer), to produce output that is both relevant and engaging. It adapts in real-time to match the evolving needs of users. One of Brainy's distinguishing features is its ability to process contextual input effectively. It considers various factors, including learning outcomes, learner proficiency levels, prior knowledge, and learning styles.

This contextual awareness ensures that the generated educational output aligns perfectly with the unique needs and goals of each user. This is how Brainy integrates the concept of Differentiated Instruction, which involves creating multiple learning paths and generating adapted content and learning activities that fit the learners' needs and abilities. This approach ensures that each learner receives instruction tailored to their individual learning styles and levels of readiness.

AI plays a significant role in educational content generation, careful consideration is given to the ethical implications. Brainy ensures that it complements rather than replaces human involvement in the teaching and learning process. Instructors have complete control to review the AI-generated content, ensuring that it aligns with educational goals and principles. This balance between personalization/adaptation and standardization is essential to maintain the integrity and effectiveness of the educational process.

Learning Platform Layer

The Learning platform layer serves as the bridge between Brainy's powerful Generative AI Model and the users – instructors and learners alike. At Augmental, our commitment to user-friendliness is evident in the design of this layer, ensuring a seamless interaction with Brainy, regardless of the user's technical background.

Within this layer, users find an intuitive and easy-to-navigate interface. Instructors and learners interact with Brainy through the platform, providing input, setting parameters, and receiving output in a straightforward manner in simple and easy steps. This layer encapsulates the complexity of the AI model.

In Figures 1 and 2, the final row illustrates the output received by instructors and learners, showcasing the various suggestions, real-time feedback and analysis.

Evaluation Layer - Feedback and Iteration Mechanisms

To continually improve its performance, Brainy incorporates feedback loops and iteration mechanisms. Instructors can provide feedback, directly on the platform, on the generated content, allowing Brainy to learn from its trials and refine its output over time. This iterative process ensures that Brainy becomes increasingly proficient at tailoring content to specific educational contexts.

Ensuring Ethical Use and Learning Efficacy

In this section, we will discuss the ethical considerations and measures in place within Brainy's architecture to ensure responsible use and optimize learning outcomes.

Brainy's architecture ensures responsible use and learning efficiency. All data sent to the generative AI is anonymized, devoid of personal user information, and designed to prevent any attempts at user identification. Brainy prioritizes ethical AI practices, constantly adapts to evolving educational methodologies, and upholds stringent data privacy and security measures.

Brainy's architecture supports continuous learning and adaptation. It keeps pace with evolving educational methodologies, ensuring that the content it generates remains aligned with the latest pedagogical insights and practices. Instructors can track learner progress and assess the impact of Brainy on educational success.

Implementation Results and Analysis

This section presents an assessment scenario aimed at determining the learner's ability to perform simple arithmetic calculations. The specific test item is an elementary-level mathematical equation.

Use Case

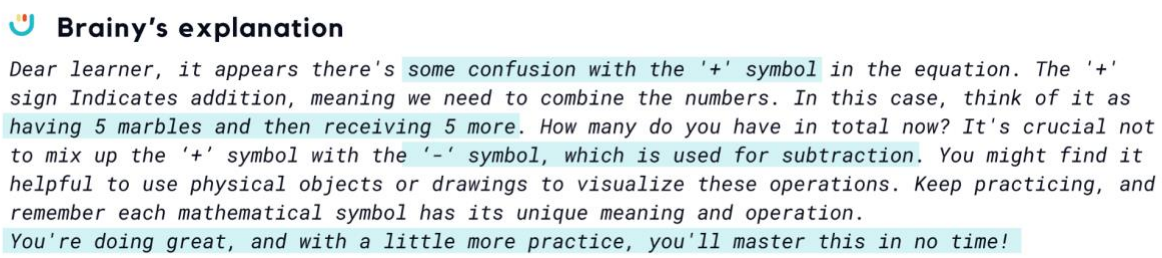
Equation presented to the student: 5+5
Answer options provided:

- Option 1 : 0
- Option 2 : 10
- Option 3 : 25

Results

Case 1: A student selects the answer "0". This selection indicates a fundamental misunderstanding of addition operation principles or possibly a misinterpretation of the question's format.

The feedback provided by Brainy:



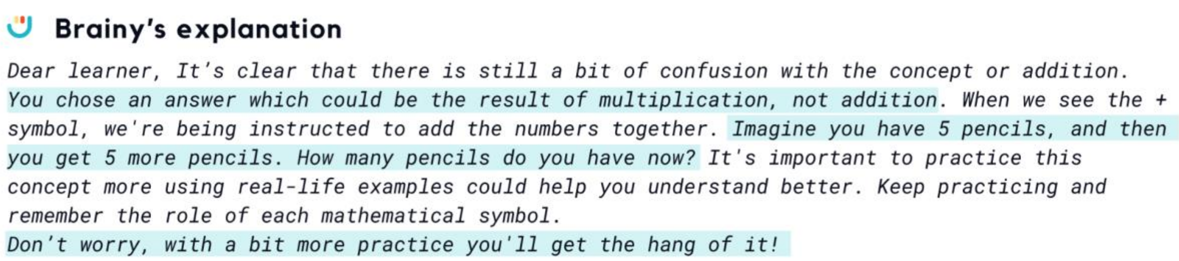
Brainy's explanation

Dear learner, it appears there's some confusion with the '+' symbol in the equation. The '+' sign Indicates addition, meaning we need to combine the numbers. In this case, think of it as having 5 marbles and then receiving 5 more. How many do you have in total now? It's crucial not to mix up the '+' symbol with the '-' symbol, which is used for subtraction. You might find it helpful to use physical objects or drawings to visualize these operations. Keep practicing, and remember each mathematical symbol has its unique meaning and operation.
You're doing great, and with a little more practice, you'll master this in no time!

Figure 3: Brainy's feedback for case 1

Case 2: A student selects the answer "25". Similar to Case 1, this selection indicates a fundamental misunderstanding of addition operation principles or possibly a misinterpretation of the question's format.

The feedback provided by Brainy:



Brainy's explanation

Dear learner, It's clear that there is still a bit of confusion with the concept or addition. You chose an answer which could be the result of multiplication, not addition. When we see the + symbol, we're being instructed to add the numbers together. Imagine you have 5 pencils, and then you get 5 more pencils. How many pencils do you have now? It's important to practice this concept more using real-life examples could help you understand better. Keep practicing and remember the role of each mathematical symbol.
Don't worry, with a bit more practice you'll get the hang of it!

Figure 4: Brainy's feedback for case 2

Results Analysis

Based on the feedback provided by Brainy in both cases (Figure 3 and Figure 4), here are some observations about Brainy, in particular, in alignment with the studied scenario.

- **Educational Approach:** Brainy has a supportive and educational approach to addressing mistakes. The language used is positive and encouraging, aiming to motivate the learner rather than criticize.
- **Conceptual Clarification:** Brainy focuses on clarifying fundamental concepts. In the studied scenario, mathematical operations are explained, especially addition. The feedback is aimed at correcting the learner's misunderstanding of the '+' symbol and its operation.
- **Use of Analogies:** Brainy employs everyday analogies (marbles and pencils) to relate abstract mathematical concepts to tangible items, which can help learners' better visualize and understand the addition process.
- **Attention to Individual Learning Needs:** The feedback is personalized to the learner's particular mistake, showing that Brainy tailors the response to address individual misunderstandings rather than providing generic advice.
- **Differentiation of Symbols:** Brainy clearly differentiates between the '+' and '−' symbols, addressing the possible confusion between addition and subtraction in the first case and addition and multiplication in the second.
- **Reassurance and Confidence Building:** The feedback includes reassuring phrases like "Don't worry" and "You're doing great," which can help build the learners' confidence and reduce any anxiety related to the learning process.
- **Recommendations for Learning Strategies:** Brainy suggests using physical objects or drawings as a strategy for understanding mathematical operations, indicating a preference for interactive and visual learning methods that can aid in comprehension.
- **Emphasis on Practice:** There is an emphasis on the importance of practice and the belief that with continued effort, the learner will improve. Brainy encourages the learner to keep practicing, reinforcing the idea that mastery comes with time and practice.

Conclusion

In this paper, Brainy, a context-aware AI engine integrated into the Augmental Adaptive Learning platform, was introduced as a solution to the challenges of implementing Differentiated Instruction (DI) in traditional classrooms. Brainy personalizes content and learning experiences, implements core DI components, and provides multiple learning paths tailored to individual student needs. Its architecture includes a data layer, generative AI engine, learning platform, and evaluation layer, ensuring comprehensive DI implementation. Brainy offers diverse and personalized content, assists instructors in monitoring student engagement, and provides constructive feedback. The implementation results demonstrate that Brainy has a supportive and educational approach, clarifies fundamental concepts, uses analogies to aid understanding, and tailors feedback to individual learning needs.

Further experiments and data analysis are in perspective to comprehensively evaluate Brainy's efficacy and accuracy in enhancing Differentiated Instruction (DI) and improving educational outcomes. By analyzing the impact of Brainy on learning engagement, motivation, and learning outcomes, instructors can better understand its potential benefits and areas for improvement. Additionally, these evaluations can inform the refinement of Brainy's algorithms and features, ensuring that it remains aligned with educational goals and principles and maintains a balance between personalization and standardization. This ongoing evaluation process is essential for ensuring that Brainy continues to meet the evolving needs of instructors and learners.

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