

# A Conceptual Design of a Generative Artificial Intelligence System for Education

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## ABSTRACT

Artificial Intelligence (AI) and, more specifically, Generative Artificial Intelligence (GenAI) are among the most trending disruptive technologies, offering unprecedented possibilities for innovation in education by customising learning paths, fostering creativity, and bridging knowledge gaps. Gen AI is a subfield of AI which generates content (text, image, audio or video) that is comparable to human-generated content. It uses complex Machine Learning (ML) models and Neural Networks (NN) trained on large datasets. The launch of ChatGPT in November 2022 has significantly raised the standards for generative artificial intelligence capabilities. Since then, researchers and practitioners have extensively investigated the potential applications of this technology. Consequently, GenAI has been applied in various sectors, including business and marketing, media and entertainment, arts and design, research and innovation, and education. While it is evident that GenAI has a high potential transformative power on education, its actual application in classical educational settings such as schools and universities remains limited to individual (student or teacher) trials without institutional guidance and support. The aim of this is expressed in two points: (1) to explore the advances in GenAI and provide guidelines on leveraging the technology in the context of learning and teaching. (2) to identify the main barriers to adopting GenAI in education and how to address them when building a Gen AI application for education. The paper's main contribution is conceptualising a Gen AI system for learning and teaching. Such a system produces course content, exercises, and supplementary materials tailored to the curriculum and each student's learning pace and style. This system will enhance comprehension and retention, making education more accessible and effective. Secondly, the research addresses the ethical issues and other barriers to adopting GenAI in education.

**Keywords**— Generative Artificial Intelligence, Innovative Education, Accessible and Effective Education, Personalised Learning, Ethical Generative AI

## INTRODUCTION

The release of ChatGPT in November 2022 has marked an important reference point in the field of Gen AI. It is the most remarkable point where Gen AI moved from laboratories and became a popular technology with real potential applications for businesses, organisations, and even individuals. The first reactions towards ChatGPT in education have been a mixture of opportunity and threat. Some regarded ChatGPT and the Gen AI tools as avenues to circumvent genuine learning opportunities, leading to misinformation [1]. With time and the embracing of technology by tech giants like Microsoft and Google, who quickly developed similar products to ChatGPT, the views and perceptions have gradually shifted and become more positive. Fütterer et al. [1] rightly observe that education is the main topic in the discussions around ChatGPT. Today, it is well established that Gen AI is a game changer for education. Despite the considerable agreement around the potential of Gen AI for education, there is still little or no clear, structured way to leverage these potentials into educational systems. The purpose of this paper is first to

summarise the potential of Gen AI for learning and teaching, as well as the challenges to generalising its adoption. Secondly, to provide a conceptual design of a Gen AI System for learning and teaching, a system that can be adopted at the institutional level, guided by educational policies and addresses ethical and privacy concerns.

This paper focuses on teaching and learning; personalised learning path, feedback, interactivity, assessment, and professional development (for teachers) are the core features that a Gen AI system for education must provide. The following paragraphs expand more on these areas.

Personalised learning is one of the most cited advantages according to several authors [2], [3] who have studied the possible impact of Gen AI on education. According to Fernandes et al. [3], personalised learning is about tailoring education experiences so that each learner can cope. The learning system can be adapted to their needs, preferences and pace. Gone are the days of the “one-size-fits-all”, as they call the traditional learning systems. The authors also make a pertinent observation that personalised learning is a must in the education sphere, which is dominated by Massive Open Online Courses (MOOCs), as well as online and e-learning. Therefore, Gen AI should be seen by educators and technologists as a critical technology for the future of education.

Feedback is another key pedagogical component that impacts drastically on students’ performance [4], [5], [6]. With such importance given to feedback, all possible avenues for constant and regular feedback must be explored to make education more efficient. Gen AI tutors and tools are unlike human instructors; they are not time-bound, subject to fatigue, and unavailable. They can always be available to the learner, responding instantly to their requests and providing instant review and marking of the student’s work [7]. A Gen AI system providing swift feedback to students is also a great advantage for instructors who can focus on tasks requiring more intelligence and expertise.

While feedback is about responding to a student’s submission or request, another essential educational concept is interactivity, which deals with the student’s participation in class discussions or activities. However, interaction cannot happen in isolation; it requires the engagement of another party. Gen AI tools, chatbots, and tutors can always be activated and made available to provide the environment for interaction at demand for students, which is more convenient than the traditional classroom [8].

Assessment is probably the area of teaching and learning that has been the most challenged with the advent of Gen AI tools like ChatGPT. Most initial resistance towards using Gen AI was because these tools rendered the traditional way of assessing students obsolete and required a new way of conducting assessments. [9] said: “The use of AI in high-stakes assessment is an area that requires further exploration and innovation.”[9].

Finally, professional development, the last of the features considered in this paper, is also a key area where Gen AI has the potential to revolutionise the lives of instructors and educators at large. The content generation capacity is good news for instructors who can quickly produce course content, examination subjects, and other evaluation elements in time records. The continuous education of instructors is made more manageable, effective, accessible, and affordable.

This paper has, therefore, contributed to bridging the gap in moving from individual trials of Gen AI to an institutional adoption of Gen AI in learning and teaching. The Gen AI capabilities have been described in general, highlighting many other possibilities that can also be demonstrated in different research works to uncover more and more about the use of Gen AI in education. The main challenges and barriers to adopting Gen AI in education have also been discussed and incorporated into the proposed solution.

The remaining part of the paper is organised into four sections. Section II presents the related work and

shows the literature gap that justifies the work of this study. Section III describes study's methodology, leading to the formulation of features and requirements of the Gen AI system for learning and teaching. Next, section IV describes the results and discusses them. The paper concludes with section V, where the work is summarised, the main results highlighted, and directions for future works are presented.

## RELATED WORKS

Gen AI has attracted a lot of attention in the past two years. As of February 4, 2024, a Google Scholar search with the keywords "Generative AI" produced a list of 913,000 results. The results remain relatively high by narrowing the search with "Generative AI in Education" (242,000). If we filter the previous results by limiting the range of publications to 2022 to the present, the list holds 42,100 results, meaning that 42,100 publications have been made on this topic in two years. To analyse such a volume of literature is not an easy task. This paper considers two aspects: Gen AI capabilities and challenges for education. In this section, we first present the educational capabilities of Gen AI, then introduce the challenges to the adoption and implementation of those capabilities, and finally, we end with a summary of the main points in the current literature as well as the existing gaps.

### Generative Artificial Intelligence Capabilities for Education

Following the four key domains: learning, teaching, assessment and administration proposed by [10], the paper organises the Gen AI capabilities using these domains for grouping.

**A. Learning:** In learning, motivation, engagement, academic performance, personalised learning or adaptation, feedback, critical thinking, and interactivity are the most common capabilities, and the existing literature advocates that Gen AI can be leveraged to provide improvement and even innovation.

1. *Motivation:* Several studies have concluded that Gen AI increases students' motivation. [11] conducted empirical research where students in a computer programming course were divided into experimental and control groups. The experimental group members have access and have used Gen AI (ChatGPT in this case), but the control group did not use the tool. The research findings revealed that motivation, computational thinking skills, and programming self-efficiency were much higher than the control group members. [12] conducted an experimental study that indicated more positive motivation characteristics than negative ones were observed in students learning with ChatGPT. The authors concluded that Gen AI is suited to promote students' motivation to learn and can contribute to improving their learning performance. Other literature in support of Gen AI to increase students' motivation include [13], [14], [15], and [16]. Contrary to what has been presented, other studies consider that Gen AI may negatively impact students' motivation. [17] argue that Gen AI may also lead to lost motivation, especially for students in remote areas without proper access to the internet.
2. *Engagement:* Engagement in education refers to how actively a learner interacts with the learning content and environment. In the literature in general, most authors who see the positive impact of Gen AI on motivation have also seen its potential for increasing students' engagement. According to Yakin et al., the use of ChatGPT raises the level of student engagement by creating more enthusiasm and facilitating activities such as idea exchange, discussions, analysis, and motivation [18]. [19] argue that the use of Gen AI provides experiential learning, motivating and engaging students in achieving their learning objectives. [20] state that the immediate feedback provided by Gen AI, like ChatGPT, enhances students' engagement and contributes to the overall improvement of education. Several other studies, including [19], [21], [22], and [23], also support the idea that Gen AI contributes to raising the engagement of students.
3. *Performance:* In most of the papers perused, those supporting Gen AI for motivating and engaging students also argue that Gen AI contributes to improving students' performance. In [24], the authors

developed a Gen AI-based model that provides feedback and generates automatic questions. Through an empirical study, the model has improved students' understanding and thinking capability, achieving an efficiency of 94.3%. Many others supporting Gen AI to enhance students' performance include [25].

4. *Personalised Learning*: In the traditional teaching system, one curriculum, with often limited options for delivery and assessment, is offered. It is hard for the teacher to provide a personalised path, especially with large class sizes. Gen AI is perceived as a solution that provides personalised learning. "When students struggle with assignments, GenAI can act as a virtual tutor, providing personalised learning support and answering their questions immediately" [26]. Other papers supporting that Gen AI provides personalised learning include [27] and [19].
5. *Feedback*: In a relatively old study by Rivers and Koedinger in 2013, the authors have seen the need to provide automatic feedback to students [28]. [29] also proposed an AI-based system for automatically generating feedback. Several other authors, including [30] and [24], support that Gen AI is a solution to providing immediate and regular feedback to students.
6. *Critical Thinking*: Concerning critical thinking, the views about the impact of Gen AI are controversial—some authors like [24] argue that Gen AI contributes to increasing the critical thinking abilities of students, whereas [31] and [26] have expressed the possible negative impact of Gen AI on students' critical thinking capability development.
7. *Interactivity*: Like the other features enumerated above, there is strong support from the literature that interactivity in learning and teaching can be enhanced using Gen AI tools such as chatbots [32], [33], etc.).

In conclusion, the existing literature is very optimistic about leveraging Gen AI to improve many aspects of learning. However, the strong acknowledgement of Gen AI capabilities is not accompanied by adequate practical examples and guidelines for implementing these capabilities. Most studies are either empirical, carrying out experiments with minimal scope of activities, or systematic reviews of literature.

**B. Teaching:** In the area of teaching, Gen AI turns out to be able to provide support in the following areas:

1. Content generation [17], [16], [34].
2. Providing automatic and immediate feedback to students [29], [30], [24].
3. Improving teaching strategies [35], [36].
4. Supporting teachers' professional development [37], [38], [39].

**C. Assessment:** In learning and teaching, assessment has been the aspect that raised the most concern with the advent of Gen AI. The generative power of Gen AI has been seen and is still considered a threat to the authenticity of students' written works. Many people have raised issues of academic integrity in all written submissions. The assessment in the era of Gen AI has challenged the teaching profession and calls for the rethinking of how to assess the students [40], [41], [42]. Beyond this call for rethinking the assessment approaches, it is essential to note that Gen AI has also made it easier for teachers to generate exam subjects based on specific content.

**D. Administration:** In examining existing literature, it is also found that the administration of educative institutions can benefit from Gen AI by automating tasks like grading automatic responses to students' inquiries, freeing educators to focus on teaching. [43] see the potential of Gen AI to provide sustainability in the educational sector, while [44] advocates for administrative efficiency.

## Generative Artificial Intelligence Challenges for Education

The main challenges and barriers to the adoption of Gen AI in education are accuracy or reliability, privacy

concerns, and ethical issues [26]. Besides those issues, the following are also part of the barriers to Gen AI:

1. Technological barriers and resource constraints [36],
2. Resistance to change [45],
3. Lack of policies and legal regulations framework [46],
4. Reliability is a significant concern and warns against overreliance on Gen AI models, which may occasionally hallucinate and generate false content [47].

Like with any disruptive technology, the challenges of Gen AI will be addressed progressively with time. The challenges related to the technology itself, such as the reliability or accuracy of the models, are often resolved more quickly than those relating to policies, regulations, and ethics.

### Summary and Gaps

In short, the capabilities and barriers/challenges of Gen AI for education can be summarised as shown in Table I.

Table I: Summary of Gen AI Capabilities and Barriers to Education

	Learning	Teaching	Assessment	Administration
Capabilities	Motivation, Engagement, Performance, Feedback, Personalised learning, Critical thinking, Interactivity	Content generation, Feedback, Developing teaching strategies, Teachers’ professional development	Content generation, Feedback	Automation, Administrative efficiency, Sustainability
Barriers / Challenges	Ethical issues, privacy concerns, reliability, resistance to change, lack of policies and regulations, technological barriers, and resource constraints.			

The close exploration of the existing literature has shown that the potential of Gen AI for transforming education in general and learning and teaching in particular is well established. The use of Gen AI at the individual level (by both students and teachers) is growing without any guidance and proper education on how to use it correctly. For the Gen AI potential to be fully exploited and indeed support education at a large scale, institutional frameworks must be established to guide its adoption and integrate it into the educational system. That is the most significant gap that the current study contributes to fill.

The literature review has also revealed that real challenges and barriers must be addressed for the wide-scale adoption of Gen AI. These challenges can be grossly divided into two: those related to technology, such as accuracy or reliability, security, and privacy issues, and others (ethical and legal issues, policies, etc.). Gen AI technology is maturing very fast, and with that maturity, most technology-related challenges and barriers will be resolved in the few years to come. The other group of challenges, human-related factors, will likely take more time to settle. This study has been incorporated into the design of the proposed solution to capture these human-related factors through an “Integration and Policies Compliance (IPC)” component, described



later in the paper’s results section.

## METHODOLOGY

This study aimed to identify the Gen AI capabilities for learning and teaching at higher education, as well as the challenges and barriers to its adoption, and to provide a practical approach on how to implement a concrete system to fill the gap of practical application. To achieve this goal, exploring the literature and extracting the features of an effective educational Gen AI system was necessary. The system requirements are established from the features, and the system’s design is derived from the requirements.

The research process used in this paper comprises seven steps, as portrayed in Fig. 1, where the steps are numbered to indicate the order, and the output of each step is also shown. The final output is a high-level conceptual design of the system.

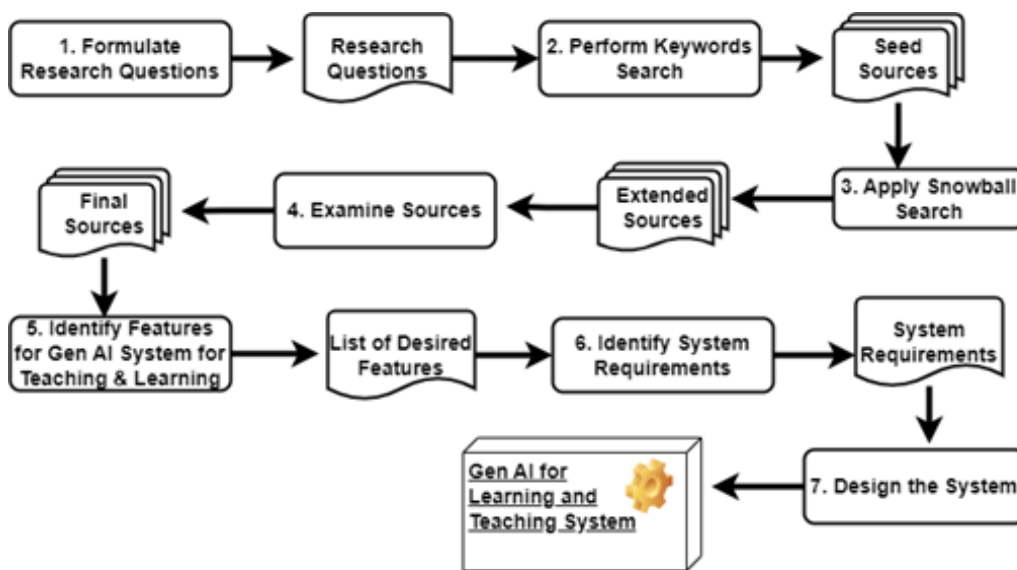


Fig. 1 Research Process

The first step of the process was to formulate the research questions. The researcher’s interest was triggered by 1) the conversations and controversies around using Gen AI in education and 2) the abundant literature about Gen AI in education. On March 14, 2024, a Google Scholar search with the search term: intitle “Generative Artificial Intelligence” + “education” with a restriction of the publication period from 2023 to date returned a result of 563 papers. Therefore, from January 1, 2023, to March 14, 2024, 563 papers whose titles contain both generative artificial intelligence and education were published. From these observations, the research questions formulated were:

1. What are the capabilities or promises of Gen AI for education?
2. What are the challenges and barriers to its adoption in education?
3. Are there practical Gen AI systems available for immediate use in the context of higher education?
4. What should be the features and requirements of a Gen AI System for education?

The questions were later narrowed down by restricting education to learning and teaching.

The second step of the process was to perform a keyword search. For this search, the study limited the publication period from 2022 to date, and the search resulted in a list of ten sources. This list of ten sources constituted the seed list for applying the snowball (next step) literature search method. The keywords used

are grouped into three categories:

1. Category 1: Gen AI or Generative Artificial Intelligence or Artificial Intelligence
2. Category 2: Education or Learning or Teaching
3. Category 3: Students or Teachers

In the third step, we applied the snowball literature search method, limiting the selection of new sources to references from the current list of papers and eliminating duplicates. After three iterations of the snowball process, we stopped, and 92 papers were selected as part of the extended list of sources.

In step 4, the 92 papers were manually skimmed, and 47 papers were finally selected to be part of the final list of sources to consider for the study. The inclusion and exclusion criteria used in the manual selection are summarised in Table II.

Table II: Inclusion and Exclusion Criteria

	Inclusion Criteria	Exclusion Criteria
Type of Publication	Is peer-reviewed work	Not peer-reviewed
Date of Publication	2020 and beyond	Before 2020
Title	Must contain a category 1 keyword and keyword either in category 2 or 3 or both.	Does not contain a category 1 keyword or has a category 1 keyword but none of category 2 nor 3.
Abstract and content	Must explicitly be about AI and address education matters	Is not about AI or is not addressing education matter.

In step 5, the 47 papers were analysed to identify the emerging Gen AI capabilities or promising features for learning and teaching. The criteria for accepting a capability or feature were that it must appear in at least 25% of the 47 papers (12). Table III provides the list of selected capabilities along with the count of papers where they were mentioned.

Table III: Generative Capabilities Citations Counts

Gen AI Capability for Education	Papers Count
Personalised Learning	18
Feedback	19
Assessment	25
Interactivity	12
Teachers' Professional Development	16

In step 6, the system's requirements to fulfil such requirements are determined using the validated list of features, as shown in Table III. A set of 16 requirements have been identified and are described under the results and discussions section.

Finally, the last step was to produce a high-level conceptual design (see following subsection) of a Gen AI system that supports learning and teaching in higher education, given the features selected in step 5.

In the next section, we present and discuss the results of applying the described methodology.

## RESULTS AND DISCUSSIONS

Following the methodology described above, the list of requirements based on the identified features was established, and these requirements are classified as the system’s functional requirements. Other requirements, called the non-functional requirements, are derived from the list of challenges and barriers identified in the literature review. This section presents the results regarding system requirements and conceptual design and then discusses the proposed solution.

### Results

**1) Functional Requirements:** The functional requirements are derived from the desired features of the system and are provided in Table IV.

Table IV: Functional Requirements of the System

Features	Requirements	
	Code	Description
Personalized Learning	Req 1	The system must have a mechanism to evaluate the student’s strengths, weaknesses, learning styles, and pace.
	Req 2	The system must be able to customise the content and suggest a learning path based on the identified challenges.
Feedback and Assessment	Req 3	They must be able to generate assessments and provide instant feedback on assignments, quizzes, and interactive activities, allowing students to understand their mistakes and learn from them immediately.
	Req 4	The system must include a progress tracking component storing information necessary for the personalisation.
Interactivity	Req 5	The system must handle interactive content like videos, simulations, and interactive exercises.
	Req 6	The system must provide chatbots or virtual assistants to offer students immediate help, explanations, or hints, facilitating a more interactive learning environment.
	Req 7	The system must allow teachers to provide input on the AI’s effectiveness and suggest content improvements, fostering a collaborative environment between the AI system and educators.
Professional Development	Req 8	The system must provide a dashboard that enables them to access detailed reports and insights into each student’s progress, helping them identify areas where students struggle and allowing for targeted intervention.
	Req 9	The system must provide professional development resources like courses, workshops, and collaboration tools to enhance teachers’ professional skills, particularly in integrating AI and technology into teaching.

**2) Non-Functional Requirements:** The non-functional requirements comprise the constraints and compliance issues the system must address. Table V gives the list of constraints along with the corresponding requirements.



Table V: Non-Functional Requirements

Constraints & Compliances	Requirements	
	Code	Description
Ethical, Privacy, and Policy Concerns	Req 10	The system must strictly adhere to data protection regulations and ensure user data is handled ethically and confidentially.
	Req 11	The system must regularly evaluate and update the algorithms to prevent and mitigate biases based on ethnicity, gender, or socioeconomic status.
	Req 12	The system must fully comply with the school/university policies related to learning and teaching.
Integration and Expansion	Req 13	The system must easily integrate with existing curriculums, educational systems, and standards.
	Req 14	The system must allow the updating and adding of new content and features to keep up with educational advancements and technological developments.
Scalability and Accessibility	Req 15	The system must be accessible on various devices and platforms, accommodating different settings and learning contexts.
	Req 16	The system must ensure that the interface and content are inclusive and accessible to students of all abilities, backgrounds, and linguistic preferences.

**3) Conceptual Design:** The system can be divided into two parts:

A. User Interface (UI): like any system, a user interface is indispensable to determine how the users communicate with the system. According to the requirements, the UI, in this case, must consider the language, accessibility options, and different learning preferences. For this system, the users are comprised of students and teachers.

B. Gen AI System (GAIS): the brain of the system providing all the functionalities expected of the system. From the list of requirements functional and non-functional, the GAIS can be divided into seven components enumerated as follows:

1. *Learning Management System (LMS)*: This component is responsible for course content, user progress tracking, and resource management. It should support multimedia content and interactive activities. Teachers upload materials, create assignments, and monitor class progress through the LMS.
2. *Adaptive Learning Engine (ALE)*: To support personalised learning, the ALE provides AI algorithms to adapt content and assessments based on individual learner profiles and performance data. It should support various learning paths, styles, and paces.
3. *Content Repository (CR)*: The CR is the educational materials, activities, and resources database. It should support tagging and categorisation for easy integration with the ALE.
4. *Feedback and Assessment (FA)*: This component provides real-time, personalised feedback and assessments. It generates quizzes, simulates dialogues, and offers constructive suggestions.
5. *Data Analytics (DA)*: It gathers and analyses data from learner interactions, assessments, and feedback to inform content updates, learning paths, and teaching strategies.
6. *Teacher Professional Development (TPD)*: Offers resources, courses, and tools for teachers to develop skills in AI-powered education, pedagogical strategies, and content creation. It includes

analytics on teaching effectiveness and student outcomes.

7. *Integration and Policies Compliance (IPC)*: This component ensures compatibility with educational standards, policies, and third-party tools, enabling seamless integration with existing school systems and external resources.

An overview of the system is depicted in Figure 2. The figure shows the relationships between the different components. This paper has not explained these relationships for simplicity and space constraints.

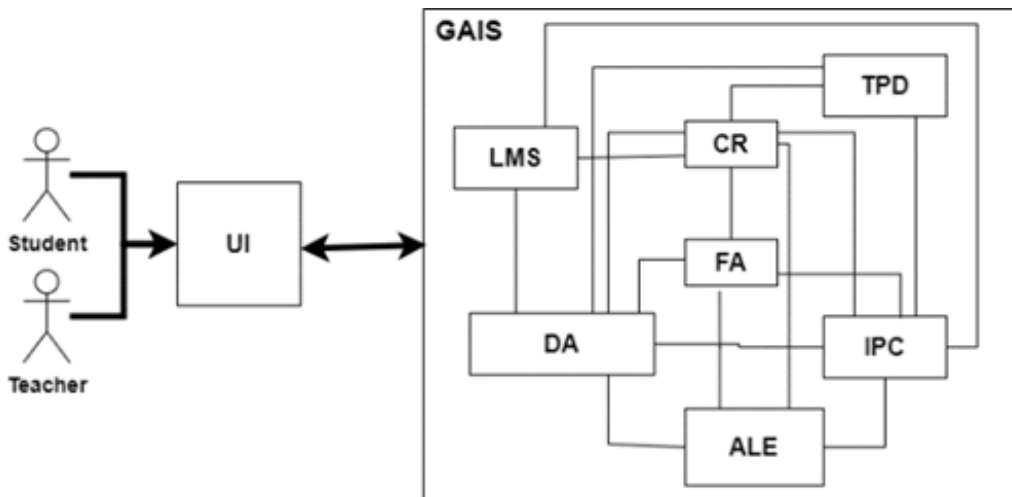


Fig. 2 Overview of the System

## Discussions

While the work presented in this paper is not a revolution, it has framed the way towards constructing Gen AI systems that can be widely and in a structured way used within an institution of higher learning. Laying out the system requirements and providing a high-level architecture of the system is a valuable contribution to adopting Gen AI in higher education learning and teaching.

The fundamental difference between this paper and previous related works lies in the fact that this work has gone beyond describing the potential applications of Gen AI to establish the requirements and architecture of a system that enables an institution of higher learning to adopt Gen AI and, therefore provide an official platform for students and teachers to make use Gen AI. If the proposed system is implemented, using Gen AI in education, will move from individual initiative to institutional levels. Adopting at the institutional level is important as it provides a guided way and ensures compliance with institutional educational policies.

## CONCLUSION

This paper has done a thorough literature review, which has enabled the author to identify the major capabilities of Gen AI for education and the challenges and barriers to its adoption. A clear methodology has been used to identify relevant literature for this study and identify the key features and requirements of a system that enables institutional adoption of Gen AI in learning and teaching. A set of 16 requirements of the expected system were enumerated and described, and the various components were identified and briefly described.

The following points summarise the main contribution of this work: 1) the identification of the Gen AI capabilities for learning and teaching, 2) the establishment of system requirements of Gen AI for the education system, and 3) the general structure of the desired system. All these pave the way towards

adopting Gen AI for education at the institutional level, providing more guidance and academic policy compliance.

While a significant step has been taken with this research, implementing the proposed solution into a product that can be deployed remains a crucial step before institutions can start benefiting from the results. Future research works will provide more detailed information and steps for the full implementation of the solution.

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