RESEARCH ARTICLE:

Design and Implementation of an Ethical AI-Based Teaching Assistant for IoT Security Education

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Abstract

Artificial Intelligence (AI) integration in education has evolved significantly, with today's AI systems surpassing conventional computer-assisted teaching methods by providing more dynamic and interactive learning environments. This study aims to design and implement an Ethical AI-based teaching assistant tailored for IoT security education, marking a new milestone in the advancement of AI in educational settings. The system focused on ethical considerations such as data privacy, transparency, and accountability, fostering a learning environment where students can think critically, explore diverse perspectives, and engage meaningfully with AI technology. Central to the project's success was a robust design phase that included carefully selecting AI algorithms, a modular and scalable architecture, an intuitive user interface, and efficient data flow mechanisms. Thorough testing and continuous improvements ensured seamless integration with existing educational technologies, enhancing learning and teaching experiences. As a result, students improved their engagement levels and ability to identify and mitigate IoT security threats, and educators experienced a notable reduction in grading time thanks to the AI's automated assessment capabilities. Additionally, the project increased student satisfaction, greater utilization of learning resources, and the publication of research papers on IoT security. This study highlights the transformative potential of AI in education and underscores the importance of ethical considerations in its application. With its comprehensive approach to design, scalability, and security, this project serves as a model for the future of Ethical AI-driven education, offering valuable insights into how AI can enhance learning outcomes and teaching effectiveness while maintaining academic integrity and data security.

Keywords: *AI-enhanced teaching; Internet of Things; IoT security; ethical AI-based intelligent agent*

Introduction

This case-study presents the design and implementation of an ethical Artificial Intelligence (AI)-based teaching assistant tailored for Internet of Things (IoT) security education. The primary objective of the study is to explore how AI-driven tools can enhance student learning outcomes in complex technological fields like IoT while ensuring that ethical considerations, such as transparency, privacy, and data protection, are thoroughly integrated into the system design. The study commenced with a baseline assessment to gauge students' IoT security knowledge. The AI-driven teaching assistant then tailored interactive lessons to each student's needs, offering real-time feedback and adjusting content accordingly. Formative assessments were woven into the learning, with the AI analysing responses to refine its approach. Dialogue-based and simulation exercises further assessed understanding, and a final summative assessment measured learning outcome. Throughout, the AI refined its algorithms based on student performance, and comprehensive reports detailed each student's progress and class modular architecture enables easy updates and scalability. This framework is grounded in the historical evolution

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of AI in education, from early computer-assisted programs of the 1970s to the sophisticated intelligent systems of today, which distinguish themselves by their ability to adapt, learn, and interact more meaningfully with learners. The increasing presence of AI in education has prompted widespread discussions about the changing roles of educators and the ethical responsibilities involved in using AI as a teaching tool. The study builds upon the intelligent agent paradigm, first introduced by Stuart Russell and Peter Norvig (1995), which has become foundational for understanding how AI systems can influence educational practices. This paradigm emphasizes the role of AI as an active agent in learning environments, interacting with students through sensors and actuators to help them develop critical skills such as problem-solving and decision-making under uncertainty. In the context of this study, the intelligent agent functions as an AI-based teaching assistant, facilitating students' ability to detect and mitigate IoT security threats while fostering a deeper understanding of ethical AI usage in education (Russell, and Norvig, 1995). This framework also highlights the importance of simulation and modelling, allowing students to engage with AI-driven tools to understand complex IoT systems. The ethical dimension of the study is rooted in UNESCO's ethical AI framework, which guides the development of systems that uphold values such as autonomy, accountability, and fairness. The AI-based teaching assistant described in this paper aligns with these values, ensuring that learners are not only equipped with technical skills but are also prepared to navigate the ethical challenges posed by AI in modern education and technology.

The integration of AI in education has garnered significant attention from researchers and educators alike, leading to the development of various frameworks and tools aimed at enhancing educational outcomes. This section synthesizes existing literature on AI in education, highlighting notable frameworks and tools while contrasting them with our approach. One prominent framework is the AI Course Design Planning Framework proposed by Schleiss (2023), which emphasizes the need for domain-specific AI education courses. This framework advocates for the establishment of a learning catalogue that outlines AI-related competencies tailored to specific domains, thereby facilitating a structured approach to AI education (Schleiss, 2023). This aligns with the findings of Black *et al.* (2024), who underscores the necessity of comprehensive research and development efforts to fill gaps in teacher training regarding AI tools and their implications for student learning. Both frameworks advocate for systematic research into pedagogical approaches, yet Schleiss's framework is more focused on domain specificity, whereas Black *et al.* (2024) work emphasizes broader teacher education and ethical considerations. In the realm of higher education, Chan and Hu's (2023) exploration of Generative AI (GenAI) reveals a complex landscape of student perceptions, benefits, and challenges associated with AI integration. Their findings resonate with the work of Gellai (2022), who discusses the influence of policy networks on AI adoption in higher education, highlighting the role of non-state actors in shaping educational governance. Both studies suggest that successful AI integration requires a nuanced understanding of stakeholder perspectives, yet Chan and Hu (2023) focus more on student experiences, while Gellai (2022) emphasizes the policy context. Moreover, the scoping review by Lee *et al.* (2021) on AI in medical education illustrates the growing recognition of AI's role across various educational fields, advocating for curricula that are informed by best practices and evidence-based approaches. This is complemented by Tolentino *et al.* (2024) review of AI curricula for medical professionals, which identifies the need for structured frameworks that address the unique challenges of AI in medical education. Both studies highlight the importance of developing tailored curricula, yet Lee *et al.* (2021) focus on undergraduate education, while Tolentino *et al.* (2024) encompasses a broader range of medical education levels.

The ethical implications of AI in education are also a critical area of discussion. Holmes et al. propose a community-wide framework for addressing ethical concerns in AI applications within educational contexts (Holmes *et al.,* 2021). This is echoed by Barnes and Hutson (2024), who examines strategies for mitigating bias and promoting fairness in AI systems used in higher education. Both works emphasize the need for ethical considerations in AI deployment, yet Holmes *et al*. (2021) advocate for a community-oriented approach, while Barnes and Hutson (2024) focus on practical strategies for bias reduction. In contrast to these frameworks, our approach emphasizes a holistic and interdisciplinary model for AI literacy in education, as articulated in the ED-AI Lit framework proposed by Allen (2023). This framework encompasses six components, namely: Knowledge, Evaluation, Collaboration, Contextualization, Autonomy, and Ethics, aiming to provide a comprehensive foundation for AI literacy that informs research, practice, and policy (Allen, 2023). Unlike the more specialised frameworks discussed, our model seeks to integrate diverse perspectives and competencies, fostering a more inclusive understanding of AI's role in education. The paper makes use of the intelligent agent paradigm that Russell and Norvig introduced in 2003. It explores the impact of learner experiences with AI on educational outcomes (Russell and Norvig, 1995). This paradigm assists in defining modern AI systems and their distinctions from traditional computer-assisted methods, providing a clear framework to comprehend AI operations in education. Understanding the proposed framework

and its ethical considerations in AI education is equally essential. The intelligent agent paradigm is fundamental for grasping how AI can shape learning environments. It examines how learners' interactions with AI as intelligent agents can foster open-mindedness and engagement with AI-based educational tools. This paradigm has greatly influenced educational practices, especially in areas such as artificial intelligence and computer science.

The agent paradigm offers a methodical way to comprehend intelligent systems, emphasising their interaction with the environment through sensors and actuators. This approach emphasises problem-solving and decision-making under uncertainty, which are crucial skills for students in many fields. Incorporating this paradigm into education has led to the use of simulations and models, enabling students to design and experiment with agent-based systems. These experiences promote deeper learning and the development of practical skills. From this viewpoint, the primary challenge in AI is to define and develop agents capable of detecting their surroundings and executing suitable actions. Translating perceptions into actions is crucial for implementing each agent effectively (Altun *et al.,* 2024). This study discusses various methods for expressing these functions, such as logical curriculum planning and decision-theoretic systems, to demonstrate how both teachers and students make decisions. The concept of a knowledge-based agent is also presented, which retains environmental knowledge from prior experiences and demonstrates how it can function more effectively. This sparks a conversation within the educational community about which types of knowledge are valuable to preserve and how best to express and rationalize that knowledge. In this context, learning serves as a tool for course designers to explore novel classroom situations they have not encountered before. This process promotes explicit knowledge representation and reasoning in the classroom. The interdisciplinary nature of the agent paradigm has facilitated the development of courses that bridge computer science with disciplines such as education, English language, psychology, neuroscience, and philosophy. The large-scale deployment of intelligent agents has made AI in education scalable, reaching students in various time zones and geographical locations. As a result of its scalability, AI in education is now accessible to a wide range of people, including those in distant or underdeveloped regions. The agent paradigm has additionally inspired scientists and educators to explore novel opportunities in AI, leading to innovations in fields such as machine learning, robotics, and natural language processing. As a result, current educational initiatives often include discussions about ethics and responsibility in AI design and implementation. The agent paradigm's emphasis on interaction and adaptation underscores the importance of adaptable and personalised learning in educational institutions (Durante *et al*., 2024). The paradigm enables learners to prepare for a future where automation and artificial intelligence will play major roles in the workforce and society. As the world becomes increasingly dependent on intelligent systems, this paradigm forms the conceptual base for education in these areas.

The impact of the agent paradigm on education has changed how teachers approach teaching AI. It prepares students to interact with a world where AI is central to many aspects of life (Smith, 2023). The implementation of intelligent agents in education involves a multi-step process that includes thorough preparation, creation, and assessment. A comprehensive needs assessment is conducted to ensure the intelligent agent can be successfully deployed in the educational environment. To determine the objectives and goals of the agent, the needs assessment identifies the unique challenges and requirements of the learning environment where it will be implemented. This process involves engaging with educators, students, and other stakeholders to understand their expectations and needs. In conclusion, this paper delves into the opportunities and challenges of integrating ethical AI systems into educational contexts, with a particular focus on technological and ethical implications. It proposes a comprehensive design for an AI-based teaching assistant aimed at enhancing engagement and learning outcomes in IoT security courses while also addressing the broader ethical considerations that must guide the use of AI in the classroom.

The UNESCO Conceptual Framework for the Ethical Integration of Artificial Intelligence in Curricula

The UNESCO framework proposed by Miao and Holmes (2023) offers a methodical approach to understanding the theoretical foundations of artificial intelligence in education. It aims to guide academics, educators, and policymakers on how to integrate AI technologies in educational settings ethically and successfully. Providing a transparent and ethical framework for the application of AI in education is crucial. The framework is customized to meet the specific needs of educational settings, while being grounded in widely accepted ethical principles. These include privacy, data security, consent, and transparency. It also examines the potential impact of AI on both teachers and students, and how prepared they are to use AI in the classroom. Factors such as optimism for innovation and discomfort with AI's opaqueness are considered (Miao and Holmes, 2023).

Additionally, UNESCO's roadmap on AI and education provides future directions for AI integration into curricula, instructional strategies, and evaluation techniques (Miao and Holmes, 2023). It addresses potential errors and disruptions caused by AI in educational institutions and suggests solutions. The roadmap emphasizes the need for research to clarify the ethical and academic integrity issues raised by AI's use in education. This framework also highlights the importance of involving diverse stakeholders, such as educators, students, parents, administrators, and AI experts, in developing and reviewing AI integration strategies. Ensuring that all voices are heard, particularly those of individuals who may be disproportionately affected by AI, is essential for ethical AI integration. Comprehensive training and professional development for educators are also necessary to ensure informed decision-making about AI use in education. This includes workshops, seminars, and resources that help educators understand the ethical implications of AI and make informed decisions regarding its application.

Establishing a transparent communication channel about AI usage in educational settings is essential. It is vital to communicate to students, parents, and educators how AI is being used, what data is being collected, and how it is processed and stored. Building educators' capacity to understand and use AI effectively is a priority. All information related to AI usage in education must be governed by policies that protect the privacy and security of both student and educator data. Emphasizing data privacy ensures that data is used only to improve education and not shared with third parties without consent. Oversight and accountability mechanisms should be established to monitor AI usage in education and address ethical concerns. Data privacy is a critical concern in the intelligent agent paradigm, which involves collecting, processing, and storing large amounts of data. Researchers must adhere to data protection laws, obtain informed consent, and implement security measures to safeguard sensitive information. Transparency in AI research is also essential, as it promotes openness regarding AI agents' design, functionality, and decision-making processes, building trust in AI systems (European Parliamentary Research Service, 2020).

The UNESCO roadmap also emphasizes the development of policies that foster the safe, responsible, and ethical use of AI in education (Miao and Holmes, 2023). These policies should include protecting privacy, addressing biases, and promoting digital literacy and citizenship. The roadmap advocates for AI integration guided by human rights and fundamental freedoms, ensuring that AI systems are designed in a way that respects these principles. This may involve creating an ethics committee or appointing an ethics officer to oversee AI integration. AI technologies should be made accessible to all students, including those with disabilities or from underrepresented backgrounds. It is important to address potential biases in AI algorithms and data that could exacerbate inequalities in education. Proper evaluation of AI integration's impact on students, educators, and the broader educational environment is also critical. Institutions must assess whether AI technologies are achieving their intended goals, being used ethically, and adapting to users' needs. Institutions should be ready to adapt their AI strategies based on new evidence, evolving regulations, and stakeholder feedback. Ethical considerations may evolve, and educational institutions must remain responsive to these changes. UNESCO's roadmap encourages the development of open-source AI educational tools and platforms that can be adapted and scaled to meet the diverse needs of educational contexts. Strengthening AI infrastructure in schools and universities, especially in areas with limited resources, is crucial for bridging the digital divide and providing equal opportunities for all learners. Finally, monitoring and evaluating AI's impact on education is essential. Collecting data on how AI is used, its effectiveness in improving learning outcomes, and its impact on educational equity is necessary to inform policy decisions and guide future developments in AI for education (World Economic Forum, 2023).

Design, Implementation, and Governance of an Ethical AI-Based Intelligent Agent for Education

The first step in implementing an intelligent agent involves evaluating the existing curriculum and research to identify common difficulties and needs. Analysing the institution's infrastructure and technology is crucial to identifying any gaps or shortcomings the intelligent agent could address. Engaging with educators, students, and other stakeholders through focus groups, interviews, or surveys is essential to gather quantitative and qualitative information on their expectations and requirements. Once the requirements and difficulties have been identified, stakeholder involvement is critical. These needs are prioritized based on their impact on student outcomes and whether an intelligent agent can effectively enhance learning. Clear and measurable goals for the agent should be established, aligned with the institution's educational objectives and strategic direction. Next, the available technologies and tools that could be integrated into the intelligent agent must be evaluated for their technical viability, scalability, and compatibility with the existing infrastructure. Testing scenarios that mimic the application of the agent in various educational settings helps identify potential problems and refine objectives. Plans to mitigate

risks related to implementation should also be developed, ensuring the agent operates as intended. Input from an ethics committee or expert panel should be sought to align the intelligent agent with ethical standards and principles. Establishing a feedback loop with stakeholders allows for continuous improvements, ensuring that the agent adapts to the evolving educational environment and remains aligned with institutional goals.

To develop an intelligent agent tailored to an educational setting, it's essential to consider both functional and non-functional requirements. Functional requirements specify the agent's actions and tasks, while non-functional requirements focus on performance, practicality, and dependability. The agent's functionality must complement learning activities, such as providing intelligent feedback or facilitating adaptive training. The agent must protect user privacy, ensure data security, and comply with legal and ethical standards. Transparency in its decision-making processes is also essential. Educational institutions must ensure that the intelligent agent aligns with community values and improves education ethically and responsibly. This comprehensive requirement analysis ensures that the agent is customized to the unique needs and goals of the educational setting. This is strongly recommended as UNESCO encourages integrating AI-related content into teacher training programs and creating communities of practice (World Economic Forum, 2023). Key steps in requirement analysis include defining functional and non-functional requirements, specifying learning objectives, and establishing the agent's autonomy and flexibility. It is also important to gather feedback from educators, learners, and stakeholders to ensure the agent satisfies expectations regarding learning tasks and interactivity.

Methodology

The study employed a pre-test/post-test design to evaluate the impact of the AI-driven teaching assistant on IoT information security education at a British-Chinese Sino-Foreign University in China. The AI-based teaching assistant was integrated into existing IoT security modules within the curriculum. The sample consisted of 325 students enrolled in IoT security courses during the university's 2023-2024 academic year. A control group was not used in this study. Instead, the same group of students was assessed before and after the intervention. The research focuses on how AI-based teaching assistants can enhance learning outcomes in IoT security education and how ethical considerations can be effectively integrated into AI systems in educational contexts. The study investigates the potential scenarios and ethical implications of incorporating AI into education. It raises crucial questions about its practical and ethical implementation in curricula, teaching strategies, assessment, and personalised learning. Initially, students underwent standardised tests to establish a baseline of their IoT security knowledge. Following this assessment, an AI-driven teaching assistant was introduced in the IoT security modules, facilitating personalised learning paths, interactive simulations, and automated assessments. After a focus group discussion, a 5-point Likert scale survey was developed to evaluate student satisfaction with the AI system. Educators also created standardised tests to assess theoretical and practical knowledge of IoT security.

Additionally, they utilised participation logs and grading time tracking sheets while analysing system usage logs from the LMS to monitor student engagement and completion rates. After the AI intervention, students retook the standardised tests to evaluate any changes in their knowledge and skills, providing further insights into the effectiveness of the AI system in enhancing learning outcomes. A paired t-test was performed to statistically compare pre- and post-course assessment scores, while descriptive statistics were used to analyze engagement and completion rates. Satisfaction survey results were compiled to assess overall satisfaction and gather specific feedback. Additionally, thematic analysis was conducted on focus group data from 35 students to identify common themes and insights.

The design and architecture of the intelligent agent are critical to its success in educational technology. This phase ensures the agent's robustness, adaptability, and ability to address specific educational needs. The selection of appropriate AI technologies and algorithms, such as machine learning, natural language processing (NLP), and computer vision, enhances the agent's functionality.

AI algorithms in detail

The AI-based teaching assistant uses advanced algorithms based on the capabilities of models like GPT-4. These algorithms enable a range of functionalities:

- **Natural Language Processing (NLP)**: GPT-4 is utilized to process and generate natural language, making communication between users and the system seamless. This allows the teaching assistant to

understand student queries, provide detailed explanations, and engage in real-time dialogue to simulate interactive learning environments.

- **Machine Learning (ML) for Personalized Feedback**: Machine learning algorithms are employed to analyse student performance data. These algorithms can predict areas where students are struggling based on their past interactions and assessment results. By analysing patterns in student behaviour, the system provides personalized learning paths, recommendations, and feedback that are tailored to each student's needs.
- **Reinforcement Learning**: The agent utilizes reinforcement learning to improve its feedback mechanisms over time. By learning from students' interactions and feedback on the system's responses, the AI refines its recommendations, improving its ability to guide students more effectively as it gathers more data.
- **Computer Vision**: In certain cases, computer vision algorithms are employed to interpret visual inputs, such as analysing diagrams or screenshots of code provided by students. This helps the AI assistant offer guidance on visual data that students might provide in courses related to IoT security.

Details on the intuitive UI

A user-friendly interface is essential to ensure that educators and learners can interact with the intelligent agent efficiently. The interface was designed with a focus on ease of use, accessibility, and clarity to accommodate a diverse range of users. Here are the key features of the UI design:

- **Clear and Straightforward Navigation**: The interface is structured with a simple navigation system that allows users to easily move between different features. A dashboard provides an overview of key areas such as personalized learning paths, ongoing tasks, and feedback from the AI assistant.
- **Responsive Design**: The interface is designed to be responsive, adapting seamlessly to various devices such as tablets, smartphones, and desktops. This ensures that learners can engage with the platform from anywhere, improving accessibility.
- **Accessibility Features**: To make the interface more inclusive, it incorporates accessibility guidelines such as text-to-speech support, high-contrast themes for visually impaired users, and compatibility with screen readers. This ensures that students with different needs can interact effectively with the AI assistant.
- **User-Centric Visual Elements**: Visual cues such as progress bars, feedback icons, and simplified text summaries provide immediate insights into student progress. The UI also supports multimedia inputs like images, videos, and simulation results, which are essential for a subject like IoT security.
- **Real-Time Interaction and Feedback**: The user interface supports real-time chat functionality, where students can ask questions and receive instant feedback from the AI assistant. This feature is powered by GPT-4's natural language processing capabilities, allowing fluid, conversational interactions. Students can also receive feedback on assignments, quizzes, and tasks through this system.
- **Modular Layout for Easy Updates**: The modular nature of the UI allows for quick updates without interrupting the learning process. New functionalities and updates can be integrated seamlessly to address evolving educational needs.

Data flow and scalability

Efficient data flow mechanisms are embedded into the system, allowing the AI to process and analyze large volumes of educational data in real-time. This ensures that the assistant provides timely and accurate responses in dynamic educational settings, such as when students submit assignments or ask complex questions. The modular design also allows independent testing and updating of individual components, ensuring that improvements can be made without disrupting the system. This adaptability is critical to meeting future educational needs and scaling to accommodate growing users and data sources.

Addressing Challenges in Integration

Challenges such as ensuring compatibility with diverse systems (like various learning management systems and third-party tools) and managing data privacy are addressed during the integration process. By aligning the selected AI technologies with the institution's educational goals and complying with data protection regulations, the system is designed to scale efficiently while maintaining privacy and security.

Development and core components of the intelligent agent

The core components of the intelligent agent, such as the decision-making engine, must be developed with a user-centric approach. Machine learning models are trained in educational data to provide personalized recommendations and insights, while NLP enables effective communication between users and the agent. Computer vision allows the agent to interpret visual inputs, enhancing its interactivity. Usability and accessibility are prioritized during interface development. A responsive design, developed using tools like React.js, ensures interactive user experience. Data flow mechanisms, such as real-time data streaming and processing, ensure the agent can effectively handle large volumes of educational data (Figure 1).

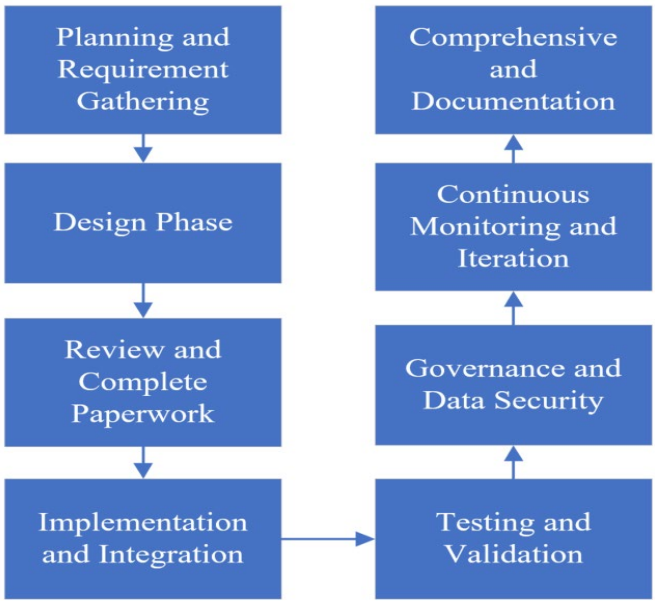

Figure 1: Design, implementation, and governance of an ethical AI-based intelligent agent

Integration and scalability

The intelligent agent is integrated into educational platforms, such as learning management systems (LMS) and student information systems (SIS), to provide seamless user experience. APIs and middleware facilitate data exchange between the agent and other educational technologies. Scalability is ensured through scalable infrastructure, load balancing, and efficient data processing techniques, enabling the system to handle larger data volumes and more users. Best practices for a user-friendly interface include straightforward navigation, consistent feedback, and accessibility options for users with disabilities. The interface supports multiple input methods like touch, keyboard, and voice.

Data governance and security

Data governance policies are embedded into the system architecture, including data encryption, access controls, and compliance with legal standards. Regular security audits are conducted to identify and address vulnerabilities. The National Institute of Standards and Technology developed the NIST Cybersecurity Framework. It comprises standards, guidelines, and best practices for managing cybersecurity-related risk. It provides a policy framework of computer security guidance for how organizations can assess and improve their ability to prevent, detect, and respond to cyber-attacks. In addition, the General Data Protection Regulation (GDPR) regulation by the European Union is designed to enhance and harmonize data protection practices across member states. It gives individuals more control over their personal data and requires organizations to protect the personal data and privacy of EU

citizens for transactions that occur within EU member states. These measures ensure the protection of user data and the system's alignment with ethical standards.

Testing and validation

The intelligent agent undergoes thorough testing, including unit testing, integration testing, user acceptance testing, and performance evaluations. Feedback from educators and students is gathered through surveys, interviews, and usability testing. This feedback informs iterative improvements to the agent's design and functionality.

Continuous monitoring and documentation

Monitoring mechanisms are implemented to track the agent's performance and user interactions. Continuous improvements are made based on feedback, with regular updates to enhance functionality and user experience. Comprehensive documentation, including system architecture, algorithms, and data flow, ensures that all aspects of the agent are recorded for future reference.

Evaluating the Impact of an AI-Driven Teaching Assistant on IoT Information Security Education

The implementation of the AI-based teaching assistant significantly enhanced student learning outcomes. A comparative analysis of pre- and post-course assessments revealed a 35% increase in students' ability to identify and mitigate IoT security threats. This was achieved through personalized learning paths, which resulted in a 30% improvement in student engagement and completion rates for IoT security modules. Pre- and post-course assessments were conducted using standardized tests to measure theoretical and practical knowledge. A paired t-test was applied to compare the two sets of scores, confirming the 35% improvement. Engagement and completion rates were tracked using data from the learning management system (LMS), comparing student behaviour before and after the introduction of the AI assistant (Figure 2). The increase in engagement was measured by the number of interactive tasks completed, participation in quizzes, and time spent on course materials, with a 30% improvement in completion rates.

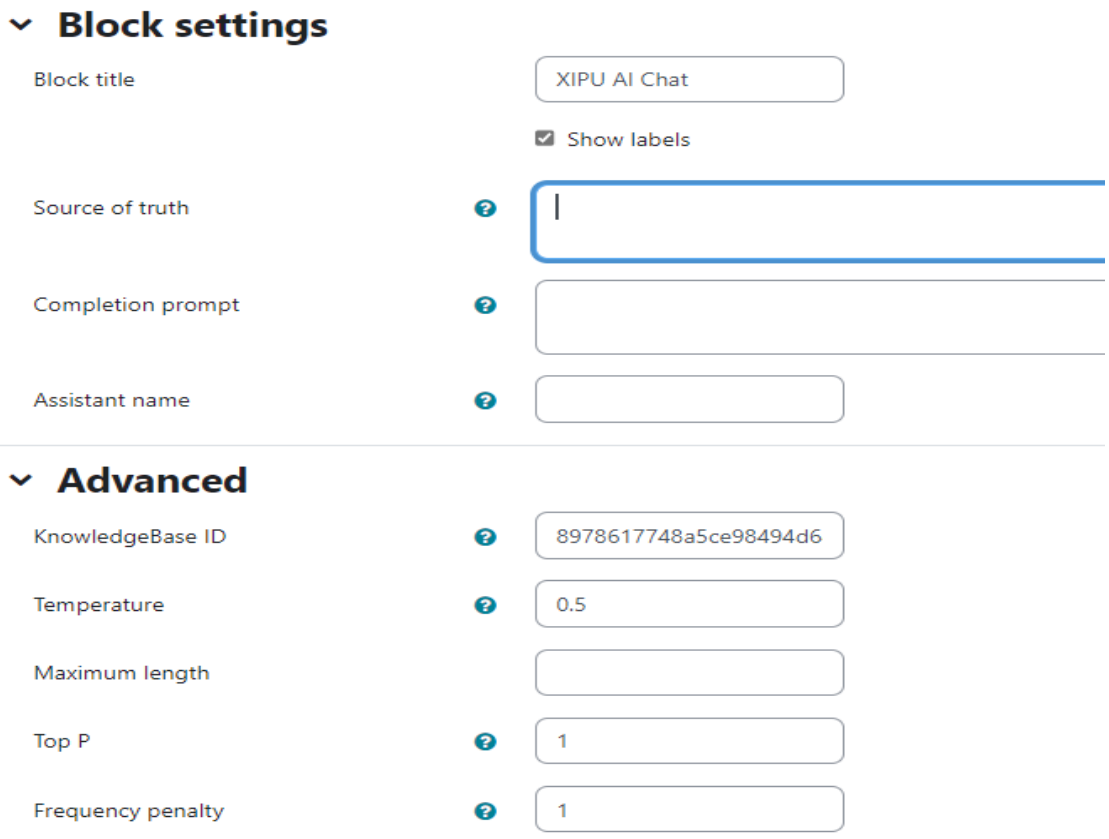

Figure 2: AI Agent configuration page sample

Regarding teaching effectiveness, educators experienced a 45% reduction in grading time thanks to the AI system's automated assessment capabilities. This was measured by tracking the time spent on grading before and after the AI's introduction. The AI-based teaching assistant also contributed to a 50% increase in class participation, as teachers reported higher interaction levels during lessons, discussions, and projects. This improvement was recorded through participation logs maintained by educators. Additionally, the seamless integration of the AI-based teaching assistant with the university's LMS led to a 25% increase in the usage of online learning resources, as the system provided personalized recommendations based on student performance. This was further validated by analysing system usage logs from the LMS (Figure 3).

Student satisfaction was measured using a survey designed with a 5-point Likert scale, assessing various aspects of the AI system, including ease of use, personalized learning paths, responsiveness, and engagement. The survey's 90% response rate revealed 92% satisfaction with the AI assistant's functionality and interface. Additionally, focus groups showed that 88% of students felt more confident in their IoT security skills, attributing this to the system's personalized feedback and interactive simulations. Students reported that the AI assistant made learning more accessible, providing instant feedback and customized recommendations that helped them better understand complex topics. Furthermore, the project fostered research and innovation in IoT security, leading to six peer-reviewed publications and the development of four innovative IoT security solutions, which were presented at international cybersecurity conferences. The AI assistant played a significant role in AI-assisted research projects, providing students with tools to apply their knowledge in real-world scenarios. The AI-based teaching assistant, hosted on Alibaba Cloud, demonstrated excellent scalability and performance, achieving 99.95% uptime and a 20% improvement in data processing speed.

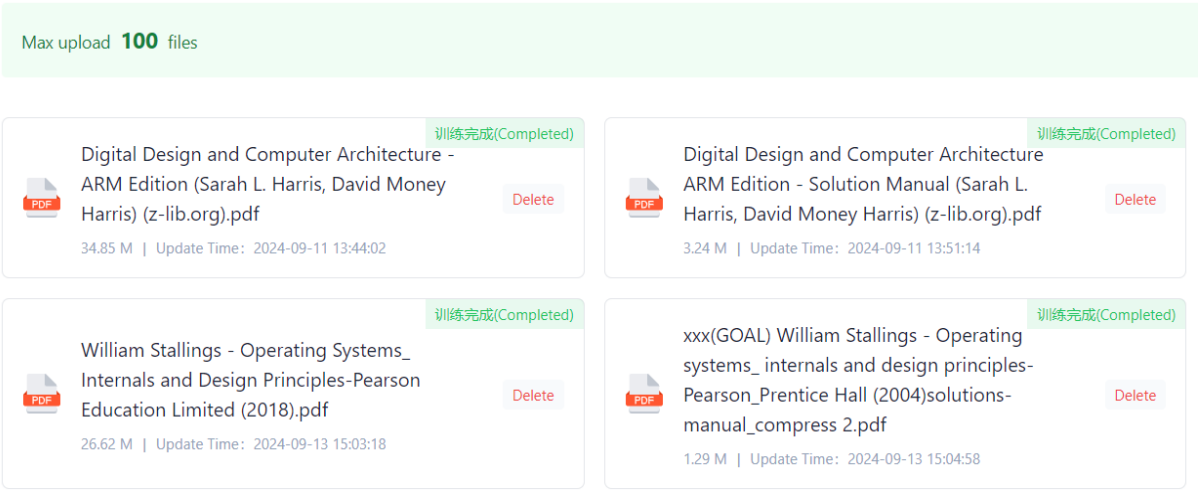

Figure 3: Knowledge base setup for virtual TA agent

Feedback from stakeholders gathered through surveys and focus groups indicated overwhelming approval of the system, with 97% of students and educators agreeing that the AI's use was transparent, fair, and aligned with ethical data management practices. A data governance policy ensures user data's ethical and secure management, with no reported breaches or incidents. Continuous improvement was emphasized throughout the academic year, with five significant updates rolled out, resulting in a 25% increase in the accuracy of the AI system's predictive analytics and personalized recommendations (Figure 4). This project also had a broader impact on educational practices within the university, leading other departments to adopt similar AI-powered tools and fostering interdisciplinary research on AI in education. Plans have been developed to extend the AI assistant's capabilities to different areas of information security and computer science education, ensuring sustainability and continued growth through partnerships with industry.

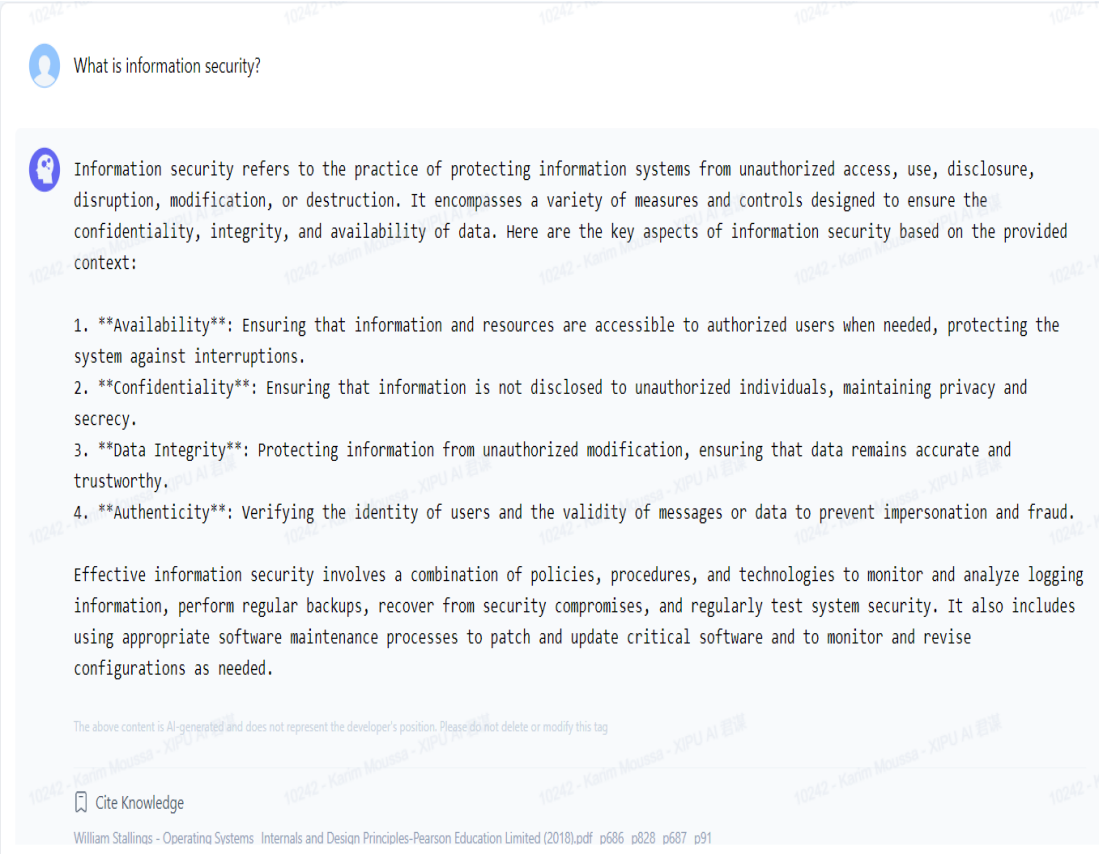

Figure 4: Virtual agent interface and sample question and answer session

This case study illustrates the transformative impact of the AI-based teaching assistant on IoT information security education, showcasing improvements in student learning outcomes, teaching effectiveness, research innovation, and overall educational practices.

Conclusion

The successful technical design of AI integration in education begins with selecting a scalable and reliable AI infrastructure that can meet the dynamic processing demands of modern educational environments. Cloud-based solutions offer unparalleled resource management and flexibility but choosing AI platforms and tools that seamlessly integrate with existing systems is critical. Flexibility, ease of use, and compatibility with current technological ecosystems are essential for ensuring smooth integration and minimising disruptions. Furthermore, robust data management practices must be implemented to ensure that student data is handled securely, in compliance with legal regulations, and aligned with strict privacy laws. AI applications, such as intelligent tutoring systems or adaptive learning platforms, can be customised to meet specific educational needs, offering personalised learning experiences that cater to diverse student populations. One of AI's most transformative potentials lies in the automation of assessments and feedback, allowing for the creation of adaptive tests tailored to each learner's unique skills, knowledge gaps, and learning preferences. This can revolutionise assessments by providing immediate, personalised feedback and fostering a more responsive learning environment. Ensuring the security and safety of AI systems is non-negotiable, with rigorous safeguards needed to protect against cyberattacks, data breaches, and any risks to the users' physical and mental well-being.

The ethical implications of AI in education described in the UNESCO framework strongly emphasise establishing an environment that encourages students' awareness, critical thinking, and ethical behaviour. Key pillars of the project include academic integrity, autonomy, accountability, data privacy, openness, and the explainability of AI. Moreover, AI systems in education must be designed with scalability and future maintenance in mind. As educational institutions evolve and integrate new technologies, the AI infrastructure must be able to grow and adapt alongside these developments. A well-defined maintenance plan and regular updates will ensure that AI tools remain functional, up-to-date, and capable of meeting the organisation's needs as they change over time. Looking

ahead, continuous evaluation of AI integration is essential to ensure that the system remains adaptable, responsive, and aligned with the changing needs of both educators and learners. Future directions include exploring more advanced AI capabilities, such as predictive analytics to forecast student outcomes, and integrating AI with emerging technologies like augmented and virtual reality to enhance interactive learning experiences. Collaborations with industry partners could also drive the development of AI-driven educational solutions that bridge the gap between academic learning and real-world application. AI integration in education offers endless opportunities to reshape teaching and learning processes. Still, its success hinges on thoughtful implementation, ongoing evaluation, and a commitment to adapting to the evolving educational landscape.

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