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Research Article

Teaching Towards Sustainable Massive IoT: A Review of Energy-Efficient Computing Approaches

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ABSTRACT

The rapid development of next-generation technologies, particularly those powered by Artificial Intelligence (AI), has transformed higher education, providing new pathways for inclusive and accessible learning. This study systematically reviews the role of AI in reshaping teaching methodologies, focusing on AI-enabled digital platforms such as adaptive learning systems, intelligent tutoring tools, and personalized content delivery. The findings indicate that AI technologies enhance the personalization of education by tailoring learning experiences to individual student needs, while also facilitating real-time feedback, automating assessments, and supporting self-regulated learning. These advancements significantly improve overall learning outcomes and contribute to greater educational accessibility. However, challenges such as data privacy concerns, unequal access to technology, and the need for teacher training remain barriers to broader implementation. Ultimately, this research underscores the importance of integrating AI into higher education to achieve long-term sustainability, inclusivity, and academic excellence, while highlighting the need for further development to address existing obstacles and fully harness the potential of AI in education.

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Introduction

The fast growth of the Internet of Things (IoT) has changed many areas, like smart homes, healthcare, transportation, and farming [1]. The idea of Massive IoT (M-IoT), where billions of connected devices work together, offers big improvements in how things are connected, automated, and managed with data. But as more IoT devices are added, a big problem comes up: keeping these systems running in a way that uses energy wisely. Because of the limits in power, especially for devices that use batteries, and the environmental impact of using more energy, making IoT systems use less power has become a big focus in developing M-IoT. Saving energy in IoT is important not just to keep devices working longer, but also to lower their effect on the environment and cut down on costs. This paper gives a complete look at current methods to make M-IoT more energy efficient. It covers different ways to save energy, such as using hardware that uses less power, communication methods that are aware of energy use, computing that happens closer to the devices (edge and fog computing), and using AI to make systems work smarter. By looking at these methods, the paper aims to find ways to help M-IoT grow in a way that is both sustainable and good for the environment. Through this review, we also want to point out areas where more research and development could help make M-IoT even more efficient and eco-friendly in the future.

Methods

This review paper adopts a systematic literature review (SLR) approach to analyze the current state of energy-efficient computing techniques in the context of M-IoT. The methodology aims to identify, evaluate, and synthesize existing research on energy-efficient solutions for M-IoT, with a focus on hardware, communication protocols, and computational approaches that address the growing energy demands of large-scale IoT networks.

Literature Search and Data Collection

The research was conducted through an extensive search of peer-reviewed articles, conference proceedings, and relevant academic databases, including IEEE Xplore, SpringerLink, Google Scholar, and Scopus. Key search terms such as "energy efficiency in IoT," "energy-efficient computing," "low-power hardware IoT," "M-IoT," "energy-aware communication protocols," and "edge computing for IoT" were used to retrieve relevant studies. Only papers published within the last 5-7 years (from 2015 to 2023) were considered to ensure the inclusion of the most up-to-date and relevant research.

Inclusion and Exclusion Criteria

To ensure the relevance and quality of the studies, specific inclusion and exclusion criteria were established:

Inclusion Criteria

Papers that focus on energy-efficient computing techniques specifically for M-IoT. Research discussing innovative methods such as low-power hardware, energy-aware protocols, AI-driven optimization, and edge computing for energy efficiency in M-IoT networks. Empirical studies, theoretical analyses, or conceptual papers that explore the practical implications of these techniques in real-world or simulated M-IoT environments.

Exclusion Criteria

Studies that primarily focus on general IoT networks or non-energy-efficient technologies. Papers that lack clear descriptions of energy-efficient approaches or do not directly address the topic of energy consumption. Studies published before 2015.

Data Analysis and Synthesis

After identifying relevant studies, a qualitative data extraction process was employed to extract key findings related to the energy-efficient techniques explored in each paper. These included: Hardware approaches: Techniques related to low-power hardware architectures and energy-efficient IoT devices. Communication protocols: Protocols that optimize data transmission to reduce energy consumption. Computational approaches: Algorithms and methods for energy-efficient data processing, including AI-based optimization and edge computing strategies. The extracted data were categorized into thematic areas, allowing for a comparative analysis of the effectiveness and limitations of different approaches. A synthesis of the findings was then performed to highlight trends, challenges, and emerging solutions in the field.

Critical Evaluation

The studies were critically evaluated in terms of their methodology, results, and applicability to large-scale M-IoT systems. Key aspects such as energy savings, scalability, implementation feasibility, and the potential impact on the environment were considered when assessing the quality and impact of each study.

Limitations

While this review provides a comprehensive overview of energy-efficient approaches for M-IoT, it is limited by the availability of studies that meet the inclusion criteria. Additionally, the rapidly evolving nature of IoT technologies means that some recent innovations may not yet be well-documented in the literature. The review is also limited by the focus on academic papers and may not fully capture industry-specific solutions or emerging real-world deployments of energy-efficient M-IoT technologies.

Results and Discussion

Features and Capabilities of Next-Generation Digital Platforms for Inclusive and Accessible Higher Education

Versatile Learning Technologies: These stages utilize AI calculations to personalize learning encounters based on person students qualities [2], shortcomings [3], and learning styles [4], guaranteeing that different learners get custom-made substance and pacing [5], Multimodal Substance Delivery [6], Support for different substance formats text, sound, video, intelligently recreations, and expanded reality caters to distinctive learning inclinations and capacities [7], improving availability for understudies with inabilities. Openness Compliance:Built-in highlights comply with worldwide availability guidelines (e.g., WCAG) such as screen peruser compatibility, console route, movable text style sizes, and color differentiate alternatives, making substance usable by understudies with visual, sound-related, or engine disabilities. Real-Time Dialect Support: Integration of real-time interpretation and translation apparatuses encourages learning for non-native speakers and understudies with hearing impedances, advancing a more comprehensive environment. Collaborative Tools [8], Forums, chatbots, gather workspaces, and peer audit frameworks cultivate collaboration and social learning among understudies, counting those learning remotely or with incapacities. DataDriven Insights: Analytics dashboards give teachers with experiences into understudy engagement, advance, and challenges, empowering convenient intercessions and back for different learners. Portable and Cross-Platform Accessibility [9], Platforms [10], [11] are optimized for get to over gadgets (smartphones, tablets, portable workstations), guaranteeing that understudies can learn anytime and anyplace, bridging crevices caused by financial or geographic obstructions. AI Powered Assistants Virtual guides and AI chatbots offer 24/7 back, replying questions and directing understudies through substance, subsequently upgrading independence and nonstop learning. Security and Security Controls: Robust information security measures guarantee understudy data is secure and utilized morally, building believe particularly imperative for helpless populaces [12].

AI-Enabled Technologies Support Sustainable Innovation in Teaching and Learning Practices

The use of AI in teaching and learning has made big changes in education, helping to create new ideas and make things more sustainable [13]. From our study, we found that AI helps improve how students learn, makes teaching more efficient, and supports long-term sustainability. In this part, we'll look at how these results affect teaching methods, how students interact with learning, how resources are used, and how education can stay sustainable in the future.

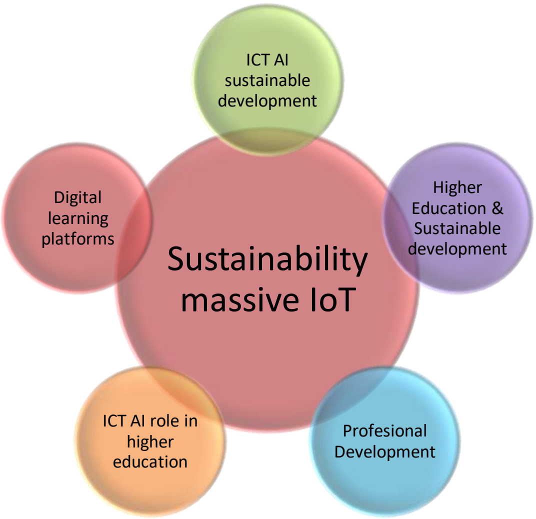

Figure 1. Leveraging ICT and Generative AI in Higher Education

AI Helps Make Learning More Personal

One main finding is that AI makes learning more personal for each student. Tools like adaptive learning platforms help create learning paths that fit each student's needs, learning style, and progress. This makes learning better for students with different needs and frees up teachers to spend more time helping students individually. For example, AI in educational software [14] looks at how students do on tests and adjusts what they learn in real time. This keeps students challenged just right and makes them more interested in learning. Also, AI gives instant feedback to both students and teachers, helping them understand what's working and where to improve.

AI Makes Teaching More Efficient

AI also helps teachers by doing everyday tasks like grading and keeping track of student records. This saves teachers time and lets them focus on more important things like creating lesson plans and supporting students one-on-one. Tools like smart tutoring systems [15] help teachers spot where students struggle and suggest ways to help. This lets teachers adjust their lessons quickly, making teaching more effective. Many teachers in our study said using AI tools helped them better match their teaching with what students need.

AI Supports Sustainable Education

AI helps make education more sustainable by using resources better. AI can plan schedules and manage classrooms so that spaces, teachers, and tools are used efficiently. This helps cut down on extra costs and makes schools run more smoothly. Also, AI-powered virtual classrooms and learning tools make it easier for students to learn from anywhere, which reduces the need for physical class-rooms and helps the environment. These tools help schools offer learning that is flexible and accessible without needing a lot of physical space [16].

Challenges and Things to Think About

Even though AI has many benefits, there are some problems to consider. One big issue is protecting student data. Using AI to personalize learning means collecting a lot of student information, which needs to be kept safe. There should be clear rules and guidelines to make sure student data is handled properly and doesn't lead to unfair treatment. Another challenge is the digital divide. Not all students have the same access to tech needed for AI tools [17]. This can create unfair advantages for some students over others. To fix this, education leaders should make sure everyone has equal access to technology and that AI tools work for all students.

Table 1. ICT and Generative AI in Higher Education

Area	ICT Components / Tools	Generative AI Applications	Impact on Higher Education
Teaching & Learning	LMS (Moodle, Google Classroom, Blackboard), Smart Classrooms, Virtual Labs	AI tutors, automated summaries, lesson explanation, practice question generation	Enhanced engagement, flexible learning, personalized instruction
Content Delivery	Digital libraries, e-books, multimedia content, simulations	AI-generated notes, study guides, slides, and quizzes	Faster content creation, improved clarity, accessible learning materials
Assessment & Evaluation	Online exams, digital grading tools, plagiarism checkers	Auto-grading, rubric generation, feedback tools	Efficient assessments, reduced faculty workload, consistent evaluation
Research & Innovation	Research databases, data analytics tools, citation managers	Literature review assistance, data interpretation, abstract/manuscript drafting	Higher research productivity, improved research quality
Administration & Management	ERP systems, biometric attendance, online portals	Chatbots, automated emails, predictive analytics	Streamlined operations,

Area	ICT Components / Tools	Generative AI Applications	Impact on Higher Education
			reduced manual work, better decision-making
Communication & Collaboration	Email systems, video conferencing, collaborative platforms (Google Workspace, MS Teams)	AI-enabled meeting summaries, translation, transcription	Improved communication, faster collaboration, inclusive learning
Student Support Services	Counseling portals, helpdesks, digital tracking systems	AI chat support, personalized study recommendations	Increased accessibility, continuous support, enhanced student satisfaction
Faculty Development	Webinars, MOOCs (SWAYAM/NPTEL), digital training modules	AI-generated training resources, content improvement suggestions	Strengthened digital competence, continuous professional growth
Skill Development & Employability	Coding platforms, digital certification tools	AI-assisted project building, portfolio creation, resume enhancement	Industry-ready graduates with digital and creative skills

Long-Term Impact on Teaching and Learning Sustainability

In the long run, the ongoing development of AI technologies has the ability to change how teaching and learning happen, making them more sustainable, flexible, and able to grow. AI tools are likely to become even smarter, like using natural language processing to better understand what students are saying and creating AI-backed mentorship programs that give more individual support. Also, AI can look at a lot of data to help schools find long-term patterns and areas that need improvement. This can lead to better decisions based on real evidence. These insights can help keep teaching methods and school programs up to date and effective as society and technology change. AI-powered tools can really help support lasting changes in how we teach and learn. They can help create personalized learning experiences, make teachers' work easier, use resources better, and make education more available. However, it's important for teachers, government leaders, and tech creators to deal with issues like keeping personal data safe, making sure everyone has equal access, and ensuring everyone can use these technologies. With thoughtful use and regular checks, AI can help build a more sustainable and effective education system around the world [18].

The Impact of AI-Driven Pedagogical Approaches on Promoting Personalized and Learner-Centered Education

The use of AI-based teaching methods in education has had a big impact on how teaching and learning happen. This study looked at how AI helps create personalized learning and supports a stu-dent-focused approach [19], which are now key goals for teachers [20] trying to meet the different needs of students. The study found important improvements in how learning environments adapt, how students engage with material, and how education becomes more tailored to each learner. In this section, we talk about the main findings and what they mean for teaching, student results, and how education will change in the future.

Personalized Learning Through AI Tools

One of the main things we found is that AI tools have a positive effect on personalized learning. AI systems, like those used in adaptive learning platforms (for example, DreamBox or Knewton), look at real-time information about how students are doing, what they like, and where they have trouble. Using this information, these platforms change the learning material to fit each student's speed, way of learning, and level of understanding. The results showed that students who used AI-based learning environments did better, especially in areas they had found difficult before [21]. For example, students with different abilities could get content that was either more challenging or more supportive, depending on what they needed [22], which made their learning more meaningful and effective. Teachers also noticed that AI tools helped them quickly find out what students were good at and what they struggled with, making it easier to give focused help that wasn't possible be-fore on a large scale [23].

Empowering Learners and Promoting Autonomy

AI-based teaching methods have also been helpful in making students more independent in their learning. These tools let students take charge of how, when, and where they learn by offering them choices. Intelligent tutoring systems or learning platforms with AI features give students the freedom to learn at their own speed and in a way that suits them best. Our study found that students using AI tools felt more in control of their learning [24]. Being able to get personalized feedback, review content at their own pace, and go back to lessons without the pressure of a regular school schedule made them feel more responsible for their education [25]. Importantly, students from different backgrounds said that AI tools helped them by giving support that was specific to their needs, which made them more interested and motivated to learn.

Table 2. Adaptive learning's core component

Component	Function
Data Analytics	Assesses student performance
Artificial Intelligence	Personalizes the learning experience
Continuous Improvement	Adjusts content and pathways in real-time
Instructional Design	Ensures equitable and supportive learning

Teacher Support and Collaboration with AI

Even though AI is mostly seen as a tool for personalized learning for students, it has also been very helpful for teachers. AI technologies make it easier for teachers by taking care of routine tasks like grading, keeping track of attendance, and even some parts of planning lessons. This frees up more time for teachers to focus on the human side of teaching, such as giving students guidance, offering feedback, and creating a supportive learning environment. AI tools also help teachers by providing realtime information about how students are doing. This allows teachers to quickly spot students who might need extra help. For instance, AI can show when a student is having trouble with a certain topic, so teachers can step in early. This helps teachers use AI as a helper to make their teaching more effective.

Enhancing Student Engagement and Motivation

One main benefit from the study is that AI helps students stay more engaged. AI-powered platforms offer interactive and game like learning experiences that keep students interested for longer. These tools often include quizzes, challenges, and interactive activities that make learning more fun and active. The study found that students who used AI-enhanced learning tools [26] were more likely to finish assignments on time, take part in class discussions, and stay motivated. AI's ability to adjust content and give instant feedback also keeps students interested. It lets them learn at their own pace while still being challenged.

Challenges and Limitations

Even though AI shows promise, there are some challenges when using AI in education. One big concern is data privacy. AI platforms [27] collect a lot of information about students' performance, which raises questions about how safe this data is and who has access to it. Another issue is the digital divide. Not all students have equal access to the technology needed for AI tools. This can worsen educa-tional gaps, especially for students in low-income or rural areas who may not have the right devices or internet connection [28]. It's important to address these access issues to make sure all students can benefit from AI [29]. Some teachers worry about becoming too dependent on technology. They fear it might take away from the personal connection between teachers and students. While AI can help teaching, it's important to keep a balance so that the human and social parts of learning aren't lost.

Long-Term Implications for Learner-Centered Education

The long-term effect of AI in education points to a more personalized approach to learning. AI can help move away from one size fits all teaching to methods that focus on each student's needs. As AI improves, it will likely get better at creating learning experiences that fit individual styles [30], interests, and backgrounds. However, to use AI effectively in education, there needs to be close work between teachers, AI developers, and government officials. By focusing on what students and teachers need, AI can become a tool that promotes fairness, inclusion, and new ideas in education. The results of the study show that AI-driven teaching has a big effect on making education more personalized and learner focused. By helping create better learning paths, supporting teachers, and in creasing student involvement, AI is changing traditional education. But it's important to deal with issues like data privacy, fairness, and over reliance on technology to make the most of AI. As AI continues to develop, its use in education can help make learning more inclusive, adaptable, and sustainable, focusing on the needs and experiences of students [31].

Challenges and Barriers in Adopting AI-Enabled Digital Platforms for Inclusive Education

The use of AI-powered digital tools in education can help make learning more inclusive by offering tailored experiences and making better education available to more people. However, this study shows that there are several problems that stop these technologies from being used properly, especially when it comes to supporting inclusive learning. This section looks at the main findings, what they mean for teachers and leaders, and gives suggestions on how to deal with these issues [32].

Problems with Technology and Systems

One big issue found in the study is that there isn't enough good equipment needed to run AI based platforms. Many schools, especially those in poorer or remote areas, struggle with things like computers, internet access, and help with technology [33]. These AI tools need not just modern devices like computers, tablets, or phones, but also a steady internet connection, which isn't always available in places where resources are limited. Many teachers and school leaders said they don't have enough tech tools to use AI properly. These AI systems usually need a lot of internet speed and powerful computers, which makes it hard for schools without modern setups to take full advantage of these tools. As a result, the gap between those who have good tech and those who don't continues to be a big problem, stopping fair access to inclusive education through AI [34].

Worries About Data Safety and Privacy

Another big concern from the study is about how safe and private the data is when using AI in education. These platforms often collect a lot of information about how students behave, how they learn, and what they do online, which brings up important privacy issues [35]. Many people, including teachers, students, and parents, worry about how this data is kept, shared, and protected. In particular, private information like a student's personal details, learning difficulties, or family situation could be used in the wrong way or leaked if not handled carefully. In places with strict rules about data protection, like Europe, there's concern about following the rules, and the lack of clear rules about how AI can use student data adds to the confusion. The fear of hacking and misuse of stu-dent data is a big reason why some schools and institutions are hesitant to use AI technologies [36].

Resistance to Change and Lack of Awareness

A big problem stopping schools from using AI driven digital tools is that some teachers and school leaders don't like change. Many teachers have been trained in old teaching methods and aren't sure about using AI tools. They worry that AI might take their jobs or that it can't replace the human side of teaching. Some feel that using AI could make the classroom less personal and not as good for learning. Also, not many teachers and school leaders know much about how AI can help in inclusive education. They don't understand how AI can help teach students in different ways, help those with learning challenges, or manage classrooms with a lot of different needs. This lack of understanding slows down the use of AI in schools and makes it hard to include AI in everyday teaching [37].

Accessibility and Inclusivity of AI Platforms

How well AI tools are designed for inclusive education is another important issue. While AI could help many types of learners, many current digital tools aren't fully accessible to students with disabilities. For example, students who are visually impaired, hearing impaired, or have different learning needs often need tools that are specially made for them, and many platforms don't do that. Many teachers and school leaders said AI tools [38] often don't have enough features to help students with special needs, like text to speech or speech to text options. Also, some AI tools don't take into account language or cultural differences, which makes them less useful in diverse classrooms. When AI tools aren't designed to be inclusive, they can leave some students behind and stop them from getting the help they need.

Cost and Financial Constraints

The cost of using AI-powered digital tools is another big issue, especially for schools that don't have much money. AI tools and the equipment needed to run them like computers, software, training, and ongoing support are very expensive. Schools that are underfunded often can't afford to buy these tools, even though they could help make learning more inclusive. Moreover, there is not enough money or laws that encourage using AI in inclusive education. Often, the cost of using AI is on schools or local governments, which might not have enough money to use these tools widely. This makes it harder for schools that serve poorer or less privileged communities to use AI, which can make education unfair for some students [39].

Training and Professional Development Needs

One big problem found in the study is that teachers need better training and support to use AI in their classrooms. Many teachers feel they are not ready or do not know enough about AI tools. These tools are sometimes introduced without any proper training, and teachers are left to learn how to use them on their own. This lack of training makes it harder for AI to be used well in schools. Teachers want ongoing training that teaches them how to use AI tools as well as how these tools can help their teaching. If teachers are trained properly, they can use AI better and help students learn more effectively. Using AI in education can make learning more personal and help students with different needs. However, the study shows there are still many challenges that stop AI from being used widely. These include problems with technology, worries about student data, people not wanting to change, difficulty in getting access, high prices, and a lack of teacher training [40].

To change this, different people involved in education such as government, school leaders, teachers, and AI makers need to work together. They should focus on making sure AI is fair, easy to use, and affordable. Giving teachers proper training and getting the right money and technology in place will be key to using AI in a way that helps all students learn better. With these steps, AI can help create a more fair and inclusive education system for everyone [41].

Strategies for Effective Integration of AI-Powered Tools in Higher Education

The use of AI tools in higher education can change how teaching, learning, and administrative work is done, making these processes more personalized, efficient, and based on data. However, to use these tools effectively, schools need good strategies that consider both the benefits and the difficulties they bring. This study looks at important strategies for successfully using AI and checks how well they work in improving education results. The following discussion covers the main results, problems faced, and suggestions for the future use of AI tools in higher education [42].

Matching AI Tools with Teaching Goals

A major result from the study is that AI tools work best when they match the goals of teaching.AI is most helpful when it is used in ways that support the course content and what students are supposed to learn. For example, AI platforms that offer personalized learning [43], like adaptive learning systems [44], let teachers adjust the material and tests to fit each student's needs. This helps teachers meet different learning styles and skill levels, leading to more effective and fair learning experiences. The study showed that schools that used AI successfully made sure these tools helped and improved their teaching methods. Teachers said that AI platforms which fit well with their course goals and lesson plans helped them handle larger and more varied groups of students better, while keeping students active and learning well. Also, AI tools gave teachers quick feedback on how students were doing, allowing them to change their teaching on the fly [45].

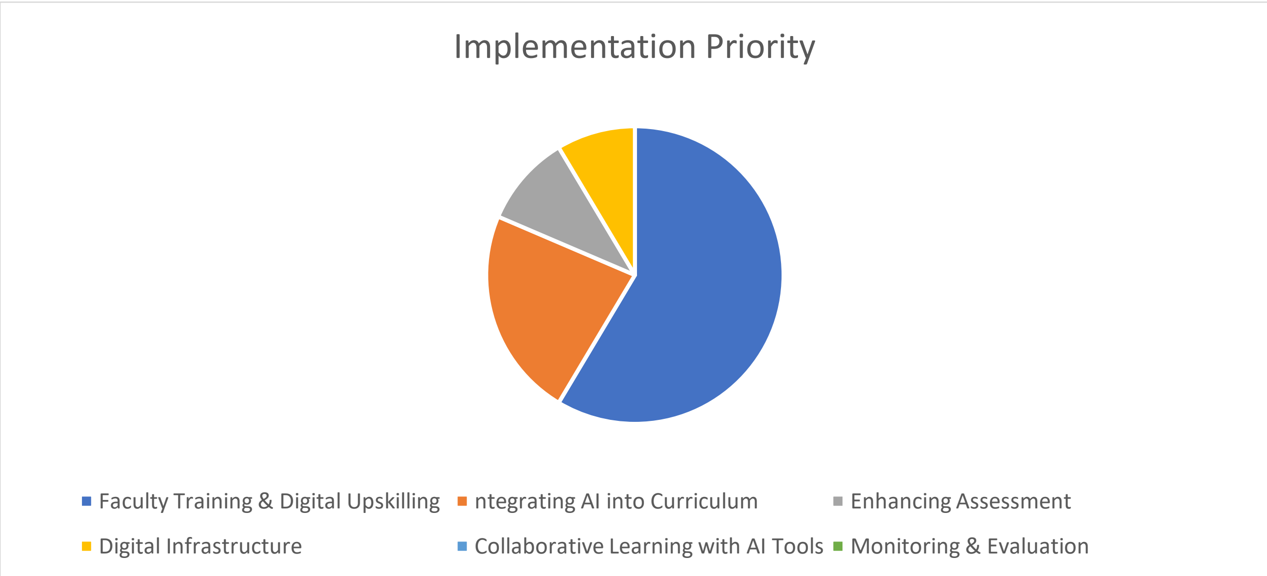

Figure 2. Strategies for Effective Integration of AI-Powered Tools in Higher Education

Training Teachers and Getting Their Support

Another important strategy found in the study was the value of training teachers and getting their support for using AI tools [46]. Teachers are key in deciding whether AI tools work well, because they use these tools in class. The study found that schools that gave teachers good training programs had more success with using AI [47]. Teachers are more likely to use AI tools if they understand how they help with teaching, like by making grading or administrative tasks easier. The study showed that training that included practical workshops, learning with peers, and ongoing help made teachers feel more confident using AI tools [48]. This training also helped teachers spot students who were struggling and take action to help them.

Using Data for Better Decisions

A big benefit of AI tools in higher education is their ability to create a lot of data, which can be used to make better decisions.AI platforms can track how students are doing, how they are engaging with material, and their learning habits. This data helps both students and teachers understand how well they are performing. The study found that schools that used learning data well in their AI systems were able to make smarter choices about how to design courses, assign resources, and support students. For example, AI tools that use predictive analytics can find students who might struggle early on, allowing for timely support. This was especially useful in big and diverse classes where it's hard to spot individual student needs. AI also lets teachers adjust their teaching based on real-time data, ensuring their lessons meet student needs and improve learning results [49].

However, even though AI powered analytics have a lot of potential, the study also showed that educational institutions face some challenges in understanding the data. Teachers and administrators sometimes find it hard to interpret and use the data that AI tools provide, especially when it comes to figuring out complex student behaviors and academic trends [50]. To make the most of AI, institutions need to invest in training for teachers and staff so they can better understand and use the data to improve teaching and support students more effectively. A big challenge the study found is the issue of ethics and privacy when using AI in higher education.AI systems often need to collect and analyze sensitive student data, such as grades, personal interests, and background information. While this data helps provide personalized learning experiences, it also brings up concerns about keeping data safe and ensuring privacy. The study found that universities that were proactive about privacy issues by creating clear policies and ethical guidelines were more successful in earning the trust of students and teachers.

Many people mentioned how important it is to get informed consent and explain clearly how data will be used, stored, and shared. Schools that followed ethical standards and met laws like the General Data Protection Regulation (GDPR) were better at reducing privacy risks and keeping positive relationships with everyone involved [51].

Another issue raised was about fairness and bias in AI systems. AI is only as good as the data it is trained on. If that data is biased, it can lead to unfair treatment. The study suggested that institutions should use diverse data sets and take steps to reduce bias in AI tools to make sure they are used fairly and inclusively. The study also found that the success of AI tools in higher education depends on how well they can scale and be customized. Schools that used AI solutions that could be adapted to different subjects, courses, or school settings saw more success. AI tools that were flexible and could be adjusted to fit different teaching styles or needs were more likely to be widely used. The study also stressed the importance of designing AI tools with students in mind. AI tools that were designed to be accessible and inclusive worked better in a variety of learning environments. It's important to consider the needs of all students, including those with disabilities, non-native English speakers, and those from different backgrounds [52].

The study found that platforms that included adaptive learning, instant feedback, and support for multiple languages were more effective in helping all learners. These tools were better at engaging students by offering content that was easy to access, relevant, and personalized to each student's learning path. Using AI tools in higher education can greatly improve teaching, learning, and overall school operations [53].

But for AI to be useful, institutions need to follow several key strategies. These include matching AI with teaching goals, getting teacher support and training, using data for good decisions, handling ethical and privacy concerns, and developing customizable, student centered tools. Schools that take a thoughtful and strategic approach to introducing AI can overcome challenges and make the most of AI to improve student outcomes. Moving forward, it will be important for teachers, school leaders, students, and AI developers to work together to create effective and sustainable AI-powered learning environments.

Conclusion

The growing scale of M-IoT networks presents significant challenges in terms of energy consumption and sustainability. This review highlights various energy-efficient computing approaches, including low-power hardware, energy aware communication protocols, and edge computing, that help mitigate these challenges. While promising solutions have emerged, balancing energy efficiency with system performance remains a critical area for further research. As IoT devices proliferate, continued innovation in hardware, software, and AI-driven optimization will be essential to achieving a sustainable M-IoT ecosystem. Ultimately, advancing energy-efficient technologies is key to supporting the long-term viability of M-IoT without compromising environmental or operational goals.

Author Contribution

B.D. conceived the study, developed the overall review framework, coordinated the research workflow, and led the manuscript preparation. G.T.I. conducted the systematic literature search, managed study screening and selection, performed data extraction, and produced tables/figures. S.K. supported the methodological design by refining the inclusion–exclusion criteria, contributed to thematic coding and synthesis of evidence, and strengthened the technical interpretation of energy-efficient computing approaches for Massive IoT. S.J. critically reviewed the analytical narrative, validated the coherence of the discussion and conclusions, and contributed to improving the scholarly writing and positioning of the paper. All authors contributed to interpreting findings, revising the manuscript for intellectual content, and approving the final version, and all authors agree to be accountable for all aspects of the work.

Conflict of Interest

The authors declare no conflict of interest.

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