

Adoption of RFID Technology in Educational Systems: A Systematic Review of Benefits and Constraints

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ABSTRACT

The related advances on the Internet of Things (IoT) have grown vastly. IoT is the most challenging platform, but it holds real promise for revolutionizing all facets of education. Many countries are using digital technologies to provide communication. Introducing IoT technologies like Radio Frequency Identification (RFID) in education will enable connectivity, enhance effectiveness, and create knowledge sharing in the learning environment. However, there is still a need to understand the opportunities and constraints of RFID as an IoT technology in education. Therefore, this paper conducts a review of the significant opportunities and challenges for RFID in education. With the introduction of RFID technology into the education sector, it is significant to understand how RFID can benefit the learning environment and support pedagogy. Hence, we bring out the benefits of RFID in educational environments. The challenges of using RFID, like security and privacy, are also mentioned. The study on RFID will be significant in accelerating its use in learning environments. Lastly, the paper highlights some future suggestions.

Keywords: Radio frequency Identification, Educational system, RFID, Literature review, Opportunities, Technologies

INTRODUCTION

The evolution of a ubiquitous computing system entails unique recognition of digital objects, with the capability to think and interface with various articles to collect information based on when the computerized moves occur [1]. IoT has brought great improvement in various sectors like medicine, security, and education [2]. Worldwide, the COVID-19 pandemic forced learning institutions to shift rapidly to distance and online study [3]. Information Technology is hence key in the academic sector [4]. RFID is one of the technologies established at the end of the 20th century to promote efficiency in work processes (Rajaram et al., 2024). Since then, RFID has seen tremendous growth in terms of the tags sold [5]. This is because of the new chipsets within the High Frequency and Ultra-High Frequency bands. RFID sensors represent a new paradigm for IoT, offering a low-cost solution with minimal maintenance requirements. This has made them appealing to healthcare, food, agriculture, and manufacturing. In education and learning, RFID can effectively track and manage student attendance. Student attendance is further linked with academic performance, reducing academic complexity and improving efficiency. Accordingly, this is key for universities' evaluation processes for students and annual audits for university assets [6]. This study looks at how RFID can be used in educational environments. It shows the benefits like tracing and tracking, among others.

LITERATURE REVIEW

RFID has experienced rapid growth in the past few years [5, 7]. It is one of the robust wireless communication gadgets that can enhance the quality of education in higher institutions. It uses tags, and the tag information can be utilized for many reasons. It operates through a reader and transmitter that communicate via an antenna [8]. The COVID-19 pandemic forced academic institutions of learning to undertake homeschooling [9]. This brings

a limitation of face-to-face teaching and on-campus study. Online classes have now been an alternative for the closure of institutions during this unprecedented time. Nevertheless, the utilization of ubiquitous devices has enabled learning to happen anytime and anywhere. This is via wireless technologies like RFID. RFID has been used in education in different ways. For instance, RFID and IoT technology can be used to improve education through supporting interactive classrooms.

The outcome showed that RFID can provide multidimensional learning. In Taiwan, RFID was used for outdoor learning and further showed effectiveness, student creativity, and motivation. Similarly, RFID has been used to monitor student attendance in Indonesia [10]. The key objective of this article is to discuss RFID as an IoT technology and its opportunities and constraints in the educational domain.

METHODOLOGY

This review was undertaken using a systematic literature review approach, following established guidelines [11] and recent frameworks applied in RFID and educational technology research [12, 13]. It outlines the methodology for identifying, analyzing, and synthesizing documents that focus on RFID technology, its opportunities, and its constraints in educational contexts. In this study, opportunities are defined as circumstances that enable or create the possibility for adopting RFID, while constraints or obstacles refer to barriers that limit its effective use in education.

A. Planning the Review

The review procedure began through a refinement of the research objectives and the formulation of a set of research inquiries. The research procedure was established, including the search string, inclusion/exclusion criteria, and quality assessment procedure for the extracted manuscripts. The details are given subsequently.

1) Review Objectives and Research Inquiries

There is a lot of increased research in education, and hence significant to evaluate the opportunities of RFID technology in education. This paper seeks to bring an understanding of RFID technology for education, the opportunities, and the constraints within the same context. The research questions entail:

- RQ1 What are the opportunities for utilizing RFID in education?
- RQ2 What are the constraints of RFID in education?

2) Search strategy

This systematic review was conducted following the established guidelines of [11] and adapted from contemporary review protocols in RFID and educational technology research [12, 14]. The methodology involved formulating targeted search strings, selecting reputable digital libraries, and applying clearly defined inclusion and exclusion criteria. Searches were carried out across major academic databases, including IEEE Xplore, ACM Digital Library, SpringerLink, ScienceDirect, Taylor & Francis Online, Wiley Online Library, Scopus, and Google Scholar. To ensure the review was both current and comprehensive, the search window covered studies published between 2010 and 2025, with particular emphasis on literature from 2020–2025 to capture post-pandemic educational shifts and recent RFID innovations. Although the Internet of Things (IoT) emerged as early as 1999 as an extension of RFID [15] the time frame for inclusion was determined by when RFID was applied in educational contexts. All retrieved studies underwent systematic screening and analysis, with the inclusion and exclusion procedures described in the subsequent section, applied consistently to every paper.

B. Planning the Review

The choice of articles is made via a set of criteria. The search criteria employed for this review were in three parts.

- C1 is a string that has the keyword RFID
- C2 is a string entailing the keywords related to challenges, for instance, “opportunities”, “constraints”, “barriers”, and “limits”.

- C3 is a string entailing the keywords related to education, for instance, “education”, “learning”, and “teaching.”

In this study, the search string shows the generic search query utilized for this review. (“RFID”) AND (“opportunities” OR “constraints” OR “barriers” OR “limits”) and (“education” OR “learning” OR “Learning”). This search string was composed in every database in the search functionality.

C. Inclusion and exclusion criteria

For the determination of the articles to be included, the following exclusion and inclusion procedure was utilized (See Table 1).

Table 1: Inclusion and Exclusion Criteria

<i>Measure for Inclusion</i>	<i>Measure for Exclusion</i>
The article should contain RFID details or RFID in education or learning	Articles that do not focus on RFID and do not address the education or learning field
The relevancy of the article to the search terms specified above	Articles failing to meet the inclusion criteria
The article must be in English and peer-reviewed	Non-English, Keynotes, editorial comments, tutorials, books slides, viewpoint
The study publication must fall between January 2010 and September 2025	Articles before 2010

D. Conducting the review

The detailed process, the extraction of the studies, and the data details from the databases are subsequently examined.

1) Study search and selection

This study followed the search strategy to choose the electronic databases. First, the outcome was a total of 400 manuscripts extracted automatically, organized, and entered into a spreadsheet. Figure 1 details the search steps. Step 2 eliminated every duplicate study. After scrutiny of the keywords, the title, the abstract, and all papers, any irrelevant manuscripts that failed to meet the inclusion criteria were removed. Most papers in the first search failed to meet the criteria. The relevant manuscripts underwent scrutiny to get the contribution of the papers and categorize them into clusters. The papers were entirely linked to RFID in education and mentioned in the search terms. Any papers that mentioned RFID as a subject were discarded as irrelevant to this study. Quality assessment further eliminated articles failing to meet the minimum criteria. The complete studies are shown in Table 2.

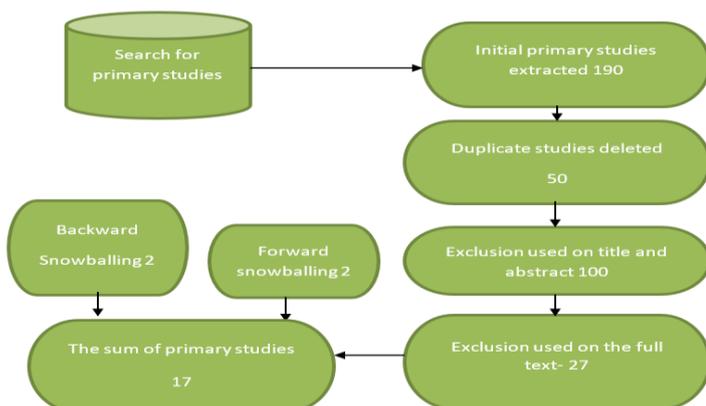


Fig. 1: Primary articles search process

F. Significant Keyword Counts

To identify dominant themes across the selected studies, a keyword frequency analysis was conducted. Table 3 presents the most frequently occurring terms, excluding “RFID.” The prominence of terms such as “system,” “attendance,” and “technology” underscores the centrality of RFID in automating educational processes, particularly attendance tracking and resource management.

Table 3: Word cloud for RFID

Word	Count
RFID	1283
system	729
technology	486
attendance	426
information	402
library	316
student	311
using	273
management	228
university	224
reader	210
tag	203
data	225
tracking	198
learning	192
integration	185
smart	174
automation	169
IoT	165

G. RFID Technology for Teaching and Learning

The COVID-19 pandemic disrupted traditional teaching and learning by restricting mobility, in-person instruction, and access to campus infrastructure (Ilieva & Yankova, 2020). In response, educational institutions accelerated the adoption of digital tools, including RFID-based systems, to streamline operations and support remote or hybrid learning environments. RFID (Radio Frequency Identification), as a foundational IoT technology, enables wireless communication between microchips and readers to transmit identifying information

[16]. It plays a pivotal role in IoT ecosystems, particularly in education, where it supports automation, tracking, and data-driven decision-making [17]. Originally developed to replace barcodes, RFID offers low-cost, unique object identification and has evolved into a versatile tool for smart campuses [18]. RFID tags come in three main types:

- **Passive tags:** battery-free, activated by reader signals.
- **Active tags:** battery-powered, capable of initiating communication.
- **Semi-passive tags:** combine passive transmission with sensor capabilities.

These tags are increasingly embedded with environmental sensors to monitor temperature, pressure, and chemical exposure, making them useful not only for asset tracking but also for health and safety monitoring in learning spaces. Recent innovations have expanded RFID's educational applications. For instance, [19] developed gamified RFID learning environments that enhance student engagement through project-based pedagogy. Similarly, [20] demonstrated how RFID integrated with AI and convolutional neural networks can support real-time behavioral tracking and adaptive learning analytics. The concept of IoT itself was built upon RFID-enabled recognition and tracking technologies, consisting of a reader and a tag. These systems are widely adopted due to their ability to identify, trace, and monitor individuals and assets in real time [17]. As RFID chipsets continue to improve in speed, range, and energy efficiency, their role in education is expected to grow, especially in smart classrooms, automated attendance systems, and personalized learning environments [18].

FINDINGS AND DISCUSSION

Every manuscript was examined, and relevant details were extracted, as shown in Table 2. The primary studies focused on the theme which is using RFID in education and learning. The focus and different application areas are shown in Table 2. The studies further show the themes coming out of each paper. Studies had a focus on the application of RFID in libraries, for teaching, for attendance tracking, and for management. From the themes, most studies (six) of all the studies are concerned with the usage of RFID in teaching and learning. Attendance is the next category, where five studies mentioned this category. The last four studies used RFID in libraries. Two studies focused on broader campus management and information services.

All selected studies mentioned the benefits of using RFID to solve problems related to improving learning, monitoring attendance of learners, managing assets and inventories in universities, and tracking and tracing items [10, 21]. IoT networks saw explosive growth during the pandemic, with campus IoT deployments increasing by over 30 percent between 2020 and 2024, laying the groundwork for robust RFID ecosystems. In relation to improving the quality of education, research agrees that RFID-enabled pedagogical frameworks support active learning, facilitate adaptive teaching strategies, and boost student engagement [19, 20]. From RQ1, this study finds that RFID has great benefits for education, such as locating learners, recording learner behavior, and providing vital information for assessment. Whereas RQ2 also points out that, despite these great benefits, RFID still faces issues such as cost, collisions, trust, and privacy concerns when safeguarding users' data.

H. RQ1: What are the opportunities/benefits provided by the RFID technology?

In learning, RFID has been used to locate students in an environment equipped with learning management systems, and it can send the location to the network, which makes it easy to communicate with other students in that environment [22]. This is because RFID tags used in RFID are small and smart and can uniquely identify different equipment and persons [19]. Mobile technology has risen because of wireless technology growth and has gained popularity too in learning. Therefore, U-learning will be fulfilled with the onward development of the Radio-frequency identification (RFID) technique. Further, the expansion in scope for future RFID will be possible with the continuous price fall. RFID technology may also detect and record the learning behaviors of students in a real environment [20]. RFID information is made available for e-learning structures. IoT technologies can help track learning behavior, track attendance while providing vital information for further assessment. Even with these advantages, RFID still has little literature, more so, RFID in education.

I. RQ3: What are the RFID constraints in education?

Not all the articles extracted in this study highlighted the constraints of RFID technology in education. However, we were still able to find articles that discuss key challenges: RFID suffers from read collisions, which occur when multiple tags respond simultaneously, and from signal interference within the system, which undermines reliability. Privacy protection entails safeguarding user data, and tag confidentiality remains a concern. Universal standards are still lacking, and integrating RFID with smart sensors adds system complexity. Although passive tags can store more data than traditional barcodes [23], they face a limited read range and require precise placement. Some studies mentioned cost as a challenge for using RFID [4], while others noted trust and privacy issues [24]. Most studies did not, however, highlight additional technological limitations.

Table 4: Summary Studies of RFID in Education

Author	Area of Application	Education level	Technology	Benefit	Constraint
[25]	Library	University	RFID	Item tracking, shelf management of resources, shelf service, and shelf efficiency improved security	Technological limitations, interference issues, prohibitive costs, lack of global standards, and privacy concerns
[26]	Learning	University	ICT & RFID	Authentic transactions, connectivity among departments, access control, attendance tracking, library management, high security, and memory storage	Not mentioned
[27]	Teaching and Learning	University	RFID	Reduce cost, increase revenue, simplify processes, save time, improve learning, improve maintenance, and communication	Trust, security, and privacy
[28]	Teaching and learning	Education	RFID	Attendance monitoring	Not mentioned
[29]	Teaching & learning	Education	RFID & IoT	Attendance monitoring	Not mentioned
[30]	Library	University	RFID	Reduce stress, increase efficiency, track and trace items, easy circulation, and checkout	Not mentioned
[31]	Library	University	RFID	Tracking, faster and accurate operations, and inventory management can handle multiple tags	Cost, tag size, lack of standards, privacy issues, and transition issues

[32]	Library	University	RFID	Information services, management of assets	Not mentioned
[29]	Teaching and learning	University	RFID & Biometric	Maintain attendance, detect location, course updates, and student monitoring	Not mentioned
[33]	Attendance	University	RFID	Attendance tracking	Not mentioned
[34]	Attendance management	University	RFID	Attendance monitoring	Not mentioned
[35]	Attendance management & information service	University	RFID	Track attendance and information management	Not mentioned
[36]	Attendance	University	RFID	Attendance tracing	Not mentioned
[19]	Teaching and Learning	University	RFID & Gamification	Enhanced motivation, project-based engagement, and technical skill development	Not mentioned
[20]	Teaching and Learning	University	RFID & AI	Real-time tracking, adaptive analytics, behavioral learning	Algorithm complexity, data privacy
[10]	Attendance	Secondary School	RFID & Cloud	Streamlined attendance, parental access, and usability	Infrastructure dependency
[36]	Attendance	Secondary School	RFID & IoT	Speed, accuracy, digital transformation	Not mentioned

CONCLUSION AND FUTURE WORKS

This systematic review has mapped the current landscape of RFID research in educational settings, revealing a modest yet growing body of work on teaching, attendance monitoring, asset management, and item tracking. While many demonstration projects illustrate RFID's potential, technical limitations, such as read collisions, signal interference, privacy and confidentiality concerns, the absence of universal standards, and added complexity when integrating smart sensors, remain persistent obstacles. Passive tags can store more data than traditional barcodes but face limited read range and require precise placement, and cost, along with trust issues, further hinder adoption. To unlock RFID's full educational impact, future research should develop lightweight cryptographic and authentication protocols tailored to low-cost tags, design privacy-preserving architectures and user-centric consent mechanisms, collaborate with GS1/EPCglobal and educational stakeholders on interoperable standards, conduct longitudinal field trials to assess usability and learning outcomes, and explore integration with IoT, edge computing, and 5G networks to enhance real-time analytics and system reliability.

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