

# Transformative Metamorphosis in Context to IoT in Education 4.0

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## Abstract

In the modern technology-driven era, it is important to consider a new model of education to keep pace with Industry 4.0. In view of this, the present paper critically explores the issues, discusses potential solutions along with a comprehensive analysis of the applications of technologies such as Internet of Things (IoT) in modern education specially Education 4.0, and examines the potential of these technologies to transform the education sector. The challenges faced by previous education models are analysed along with how they pave the way to the inclusion of IoT in education, leading to Education 4.0. The potential benefits of IoT in improving learning outcomes, enhancing student engagement and retention, and supporting teachers are also highlighted. In addition, it addresses the ethical and privacy concerns associated with the use of these technologies and suggests areas for future research.

**Keywords:** Industrial Revolution, Remote Learning, Collaborative Learning, Objective Based Education, Competency Based Education, Compound annual growth rate

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## 1. Introduction

The Internet of Things (IoT) pertains to a network of connected objects and the technology enabling communication between these devices and the cloud [1-3]. Everyday items like devices, sensors, and appliances are integrated into the internet through IoT, transforming how we live and work. The impact of IoT on society is profound, enhancing productivity, convenience, and healthier lifestyles by delegating complex tasks to machines. Coined by Kevin Ashton in 1999, the true potential of IoTs emerged about a decade later [1].

Modern education, known as Education 4.0, merges technology, including artificial intelligence (AI), big data, machine learning (ML), and IoT, to improve learning quality and access. Education 4.0 captures the impact of the fourth industrial revolution on education, giving

prominence to essential 21st-century skills such as critical reasoning, effective problem-solving, fostering creativity, and promoting collaborative teamwork [2]. The goal is to equip students for the ever-changing global economy. Education 4.0 creates a more pertinent, adaptable, and flexible education system to meet learners' needs and workforce expectations.

In this context, this study deeply examines the role of IoT in contemporary education, particularly Education 4.0, and explores its potential to reshape the sector. The study scrutinises past education models, how they paved the way for IoT in education, and the emergence of Education 4.0. It delves into the advantages of IoT such as enhancing learning outcomes, student engagement, retention, and aiding educators [3]. Ethical and privacy concerns linked to these technologies are also addressed, along with suggestions for future research directions.

## 2. Revolution in education

Education has evolved significantly from the days of the first industrial revolution, when many lacked access to education, to the current era of technology-driven smart learning. The demand for skilled workers during the industrial revolution led to the recognition of education's importance, with students following specific learning patterns. Teachers conveyed subject-specific information, and assessments gauged their comprehension. However, the integration of computers didn't fundamentally alter the educational mindset. Instead, educators harnessed technology, substituting human instructors with machines for training, learning, and assessment. Learners and teachers within the system are confined by this approach [3]. While some advanced nations progress towards Education 4.0, certain developing countries still remain rooted in Education 1.0. Hybrid educational approaches are prevalent, as rural regions stick to Education 1.0, while urban areas transition to Education 3.0 or 4.0. The educational journey encompasses Education 1.0, 2.0, 3.0, and the current and forthcoming Education 4.0, as illustrated in table 1.

Table 1. Revolution from Education 1.0 to Education 4.0

Educational Revolution	Prospective	Teacher	Student	Learning Approach	Technology Used
Education 1.0	Authoritarian	Absolute leader	Passive recipient	Teacher centric	Technology is forbidden
Education 2.0	Communication and Collaboration	Orchestrator	Active recipient	Exam-based approach, student-centric approach	Collaborative, interactive
Education 3.0	Collaborative Learning	Coordinator, advisor, and facilitator	Researcher	Student-centric, flip classrooms	E-Learning, L-Cloud,
Education 4.0	Creative Learning	Skill developer	Researcher and creator	Continuous evaluation, Learning and innovation	IoT, AI, ML, Cloud Computing, Blockchain
Education 1.0	Authoritarian	Absolute leader	Passive recipient	Teacher centric	Technology is forbidden

## 3. Issues with the education curriculum

According to a survey conducted most parents and kids were not satisfied with the education curriculum [4]. According to the analysis around 70% of students feel bored at school constantly, 80% of children experience constant stress and approximately 75% answered the question "How are you doing ?" with a negative reply. So the question arises - Why do parents and kids feel like that? The possible reasons for the same include outdated curriculum, standardized testing, poorly educated teachers and professors and low classroom engagement which are outlined in Figure 1 and are detailed as follows.

### 3.1 Outdated curriculum

Numerous schools persist with outdated teaching methods and curricula, emphasizing conventional subjects and overlooking vital contemporary abilities such as computer science, teamwork, ethics, creative thinking, and effective problem-solving. This disconnect from the evolving job landscape leaves students ill-equipped for professional life[5]. The World Economic Forum underscores the necessity for a more inclusive and current educational framework to tackle this issue [6].

### 3.2 Standardized testing

Standardized tests are often seen as neutral tools for assessing students' skills and knowledge. Nevertheless, they can be influenced by biases and worsen educational disparities. The subsequent issues are tied to standardized testing: Privileged students who receive test preparation typically outperform others; Educators lack valuable insights into their students' learning from these tests; Examinations taken under stress, frequently impact a students' performance negatively [7].

### 3.3 Poorly educated teachers and professors

Challenges arise within the education system due to educators who haven't received adequate training. This deficiency can result in misinformation and difficulties in fostering a positive learning atmosphere [8]. Overlooking ongoing professional growth can impede the adoption of new teaching techniques and technology, diminishing their capacity to offer top-notch education and motivate students.

### 3.4 Low classroom engagement

Outdated teaching approaches and a dearth of interactive learning often result in reduced student engagement in classrooms. Material that is either overly complex or lacks stimulation can cause disinterest, impacting both struggling and high-achieving students. Tailored curricula

offer a solution to these concerns, fostering improved knowledge retention and student enthusiasm [9].



**Figure 1.** Issues with the current education curriculum

## 4. Role of IoT in modern education

IoT helps to make education more geographically available, with capabilities, and status. The opportunities to integrate IoT with education systems and schools are endless. Technology can improve teaching rather than hiring new staff.

### 4.1 Task-based learning

Task-based learning in the classroom can be an effective way to help students understand a topic thoroughly. The integration of IoT in education can enhance this approach by enabling students to easily collaborate and share knowledge to complete tasks more effectively [10]. With connected devices, students can reach out to their teachers for assistance and support whenever they need it, enhancing their learning experience.

### 4.2 Accommodating with disability

Smart education IoT solutions have revolutionized the learning experience for students with disabilities, offering a more inclusive and accessible environment. IoT devices enable improved on-campus conditions, specialized education, and seamless communication with peers and teachers. For example, students who are deaf can use sign language translation devices, while visually impaired students can navigate with smart sticks and headsets. Smart doors facilitate easier navigation. Leveraging IoT technology, educational institutions can create a more fulfilling learning environment for students with disabilities [11].

## 4.3 Remote learning

Remote learning delivers education through technology, offering online courses, video lectures, and virtual classrooms. It provides flexibility, enabling students to learn at their own pace and schedule, fostering global connections and cultural exchange. Cost-effectiveness results from eliminating physical facilities and transportation needs for both students and institutions [12].

## 4.4 Tracking methods

IoT technology in education allows real-time tracking of students' whereabouts, attendance, and academic progress for improved safety and efficiency. Connected devices help identify potential security concerns and provide valuable insights for teachers. Automating administrative tasks reduces the workload, enabling a focus on quality education, creating a safer and more effective learning environment [13].

## 4.5 Resource Management

IoT devices streamline school processes, especially resource management, by monitoring electricity and water consumption. Sensors installed in lights and water taps automatically turn them off when rooms are empty, conserving energy and water. This leads to significant cost savings for educational institutions [14].

## 5. Practical tools for IoT in education

IoT technologies in education offer various benefits, including interactive lesson creation, efficient classroom management, and streamlined administrative processes. Teachers engage students with interactive lessons and receive real-time feedback on attendance and behavior. Schools achieve cost savings and improved safety through resource management and security measures. Overall, integrating IoT technologies enhances the teaching and learning experience, making education innovative and enjoyable [15].

### 5.1 Google Classroom

It is a user-friendly web-based learning management system by Google for educational institutions. It streamlines assignment creation, distribution, and grading, simplifying file sharing between teachers and students. Teachers create online classrooms, invite students, assign homework, communicate, and track progress through an online discussion platform [16].

## 5.2 Tynker

It is a platform designed for children ages 7 and above to learn coding. Tynker's self-paced courses are being used by school and educational institutions to introduce kids to coding and engage them in creative activities that make learning coding easier and more effective [17].

## 5.3 Kajeet

This application optimizes school bus operations through behaviour monitoring and Wi-Fi connectivity, boosting students' productivity while travelling. Real-time child location tracking ensures parental peace of mind regarding their safety.

## 5.4 EdPuzzle

This application offers teachers with an accessible platform to design video lessons with built-in formative assessments [18]. Videos can be assigned to students and gain insights into their progress and comprehension. Students enjoy personalized learning, and teachers track advancement through their accounts.

## 5.5 Starfall

Starfall stands as an online learning platform designed to assist kids in acquiring reading skills through a phonics-centered approach [19]. It incorporates a range of interactive games, activities, and printables suitable for home and classroom use. Beyond reading, Starfall provides animated songs, movies, and math exercises catering to pre-K, kindergarten, and students in grades 1-3.

## 5.6 Quill

This educational platform assists teachers in instructing writing, vocabulary, and grammar to students. It provides a wealth of resources, including over 400 exercises and activities, guiding students through tasks such as sentence reconstruction, passage proofreading, and composing new passages.

## 5.7 Plickers

This tool is used for formative assessment in the classroom, enabling teachers to assess students' understanding of a topic in a quick and simple manner. With Plicker, real-time data can be collected by teachers without the need for students to use paper, pencil, or any other devices.

## 5.8 Pixton

Pixton is an interactive tool for crafting comics, enabling students to craft comic strips portraying their grasp of diverse concepts. Furnished with an array of characters, comic layouts, and backgrounds, it unleashes student creativity, fostering the creation of captivating comics and storyboards.

## 5.9 LocoRobo

This IoT-based education application facilitates app design learning using programming languages like Python, Java, JS, or C. The platform optimizes the curriculum through interactions with students, enabling robotics fundamentals, drone coding, and wearable app creation for all ages [20]. Teachers access a connected coding platform, and a lesson library, and monitor student progress.

## 5.10 Magiccard

Magiccard introduces an advanced smart card system that centralizes crucial student details. It facilitates attendance tracking, medical and transportation access, and cashless cafeteria transactions. Every card is traceable, enhancing security and simplifying student location monitoring.

## 6. Three-dimensional analysis of the influence of IoT on education

The impact of IoT on the education industry can be analyzed from three different dimensions: Applications, Learning Mode, and Stakeholders [20]. In each dimension, IoT has a profound impact on how education is delivered, experienced, and managed. These dimensions of the impact of IoT on education are presented in figure 2 and are described as follows.

### 6.1 Learning modes

IoT has changed the way students access learning resources, interact with teachers and peers, and receive feedback. IoT-enabled learning modes include online learning, blended learning, personalized learning, and adaptive learning. There are different ways in which classes can be conducted using IoT.

#### Collaborative learning

Collaborative learning fosters critical thinking, problem-solving, and teamwork. It reduces plagiarism by encouraging original content creation and active learning. Integrating IoT enables virtual classrooms for global connections, promoting cross-cultural communication and

unique perspectives. Overall, it enhances student learning and produces higher-quality work.

**Virtual instructor**

This mode of education offers flexibility allowing students to access course content from anywhere, anytime. Recorded lectures provide asynchronous learning opportunities, aiding comprehension for diverse learning preferences [21]. Virtual classrooms and instructor setups enhance student engagement, enabling personalized learning. However, it should complement live interaction and feedback to maximize the learning experience. Embracing video lectures and virtual setups can prove valuable for students' understanding, provided they are integrated with other interactive forms of learning.

**Adaptive learning**

Adaptive learning is a data-driven approach that customizes the learning experience for each student based on various environmental factors. Sensors, like ultrasonic and light sensors, collect data to adjust teaching methods. Benefits include personalized instruction and an interactive learning environment, promoting student success. However, privacy and data security concerns must be addressed to gain trust and support for this innovative educational approach, which is still in its early stages of development.

**Blended learning**

Blended learning combines face-to-face teaching with online activities, offering flexibility and control over learning. It creates an integrated environment, allowing seamless transitions between modalities. This approach enhances engagement and motivation, catering to diverse learning preferences [22]. Successful implementation requires careful planning, ensuring proper integration and student support. Overall, blended learning is a valuable educational approach, empowering students with greater flexibility and choice in their learning journey.

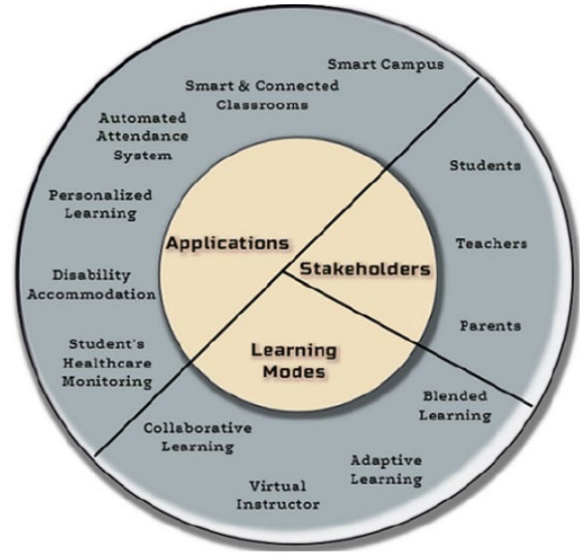
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**Figure 2.** Impact of IoT on modern education

**6.2 Stakeholders**

IoT has impacted all stakeholders involved in the education ecosystem, including students, teachers, parents, administrators, and policymakers.

**Students/Learners**

For students, IoT has enabled personalized learning experiences and improved engagement. IoT technology will significantly impact the education model from the student's perspective, in the following ways.

*Hybrid Learning:* Incorporating a hybrid learning approach involves the consolidation of subject materials, including lecture notes, assignments, and assessments, onto a unified platform. This approach empowers students with the flexibility to access video lectures from any location and at any time. By centralizing these resources, we aim to foster academic integrity and deter plagiarism, ensuring that students can engage with the content authentically.

*Accessing Resources Online:* Students will enjoy the convenience of accessing all their study materials online, eliminating the necessity to transport books and physical notes to their classes. These digital resources will be readily available through laptops, tablets, or smartphones, facilitating a seamless and efficient learning experience. This shift towards digital access not only enhances convenience but also supports academic integrity by discouraging plagiarism, ensuring that students engage

with their course materials in an authentic and responsible manner.

### Teachers/Educators

In a conventional classroom setting, the educator assumes multiple responsibilities, including delivering instruction, transcribing notes on the board, managing attendance, overseeing assignments, and maintaining records to uphold the classroom's overall environment. From a teacher's perspective, IoT in classrooms will play a vital role in managing various responsibilities with ease, such as: (i) An automated attendance system can be implemented that enables students to mark their presence using biometrics or their ID card tags, ensuring a streamlined and efficient process for tracking attendance without the risk of plagiarism or academic misconduct and, (ii) Various multimedia content types, including tutorial videos, infographics, and complex formulas, can be seamlessly presented in the classroom through the utilization of smart interactive boards, as opposed to traditional whiteboards. This innovative approach enhances class engagement and interactivity for students, ensuring a unique and dynamic learning experience while maintaining originality.

### Parents

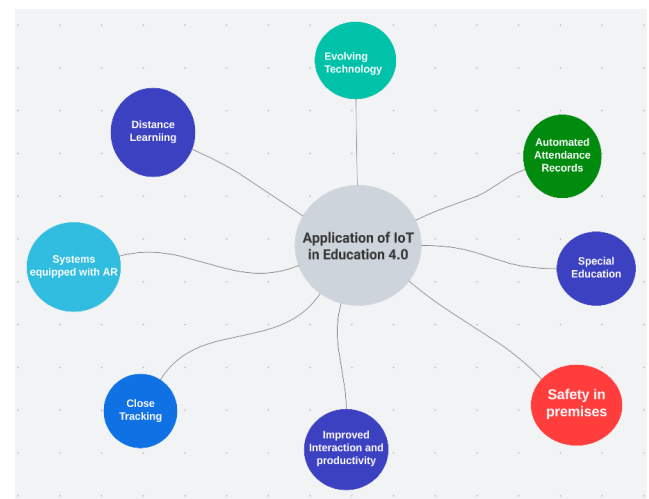
Parents can stay more informed and engaged with their children's education. IoT will also have an impact on parents as stakeholders in education, and they will be affected in several ways: (i) Through the utilization of smart wearable devices, parents can receive real-time notifications immediately when their child enters the school campus. Additionally, the live location of each student on-site can be tracked, providing comprehensive safety measures for all students present on the campus. This system not only enhances security but also ensures the originality of the information conveyed; (ii) Automated attendance and result systems serve as a reliable means to keep parents informed about their child's attendance, academic performance, class assessment records, and submission reports. This approach ensures that parents receive accurate and timely updates without any concerns about plagiarism or content duplication; (iii) Smart campuses incorporating healthcare monitoring systems will enable wearable devices to monitor students' vital health conditions, taking into account their medical history. This includes features like continuous blood pressure and heart rate monitoring. Importantly, this health information will be accessible to both students and parents, ensuring transparency and data authenticity without plagiarism concerns.

## 6.3 Applications of IoT in Education

There are numerous applications of IoT in education 4.0. The scope includes the following points as shown in figure 3 and described below.

### Evolving technology

IoT integration in education involves using internet-enabled smart devices like e-books, smart boards, and tablets with educational apps to enhance learning. Voice control for teachers, GPS-equipped school buses, and smart security cameras improve safety and convenience. Transitioning to these methods may take time, but IoT has the potential to enhance education outcomes for students, teachers, and staff [23].



**Figure 3.** Various applications of IoT in Education

### Automated attendance records

IoT technology offers automated attendance tracking using biometrics or barcodes, reducing errors and enhancing efficiency. It notifies parents about student absences and records teacher and support staff attendance. This system saves time for teachers and ensures an accurate attendance record.

### Distance learning

IoT-based systems have the capability to store and organize data using specialized software in the form of an application and website login function, allowing anyone with a user ID and password to access it from anywhere. This can offer advantages to individuals who are unable to attend conventional educational institutions yet remain committed to pursuing their education. Distance learners can access live or pre-recorded lessons, online assessments with time limits, and a portal for tracking their progress.

### Systems equipped with AR

Augmented reality (AR) enhances the real world with computer-generated graphics and sounds, aided by IoT devices. Scanning barcodes can offer engaging details, and 3D visualizations simplify complex topics like human anatomy. Educational institutions can update study materials to provide the latest information and animated displays, enriching students' learning experiences. AR's

integration with IoT technology holds promise for more effective and interactive learning opportunities.

### Special education

Previously, students with disabilities faced significant difficulties in accessing a sufficient education. IoT tools and smart devices enable adaptable educational curriculums for students with disabilities. Soundproof and light-sensitive classrooms create optimal learning environments. Sensor-connected gloves and tablets can translate sign language into verbal speech, enhancing communication beyond textbooks for better understanding.

### Safety on the premises

IoT technologies improve school safety by implementing networked camera systems for monitoring suspicious activity and activating alarms in emergencies [24]. Sensors detect fires and short circuits, enabling quick responses. Smart door locks with sensors trigger alerts and assistance calls during break-in attempts, enhancing safety and control systems' efficiency in schools.

### Improved interaction and productivity

Accessible through smart phones, virtual classrooms provide students the chance to engage and cooperate with peers. This promotes subject comprehension and meaningful interactions with both peers and educators. Additionally, the collaborative setting encourages participation in assessments, activities, and self-study through QR code scanning in textbooks, granting access to relevant digital resources.

## 7. Models of education with explanation

Teaching and learning techniques have transformed to match evolving societal needs. Both students and teachers are pivotal within any educational structure. The achievements of one influence the success of the other. Positive student outcomes indicate effective teaching, while adept educators embody successful learning strategies. The features, benefits, challenges and drawbacks of some standard education models are discussed as follows.

### 7.1 Mastery Learning Education

Mastery learning in education prioritizes mastering specific skills and concepts before advancing to more complex topics. In this approach, students have multiple chances to showcase their proficiency in a certain concept or skill, and progression only occurs after demonstrating mastery.

#### Benefits of mastery learning

There are several benefits of mastery learning. These include: (i) *Increased Student Engagement*: Mastery learning enhances student involvement through a

personalized learning encounter, enabling them to proceed at their preferred pace. (ii) *Personalized Learning*: Mastery learning offers a tailored learning journey that caters to the distinct needs and interests of each student. (iii) *Emphasis on Skills and Knowledge*: Mastery learning centers on cultivating distinct skills and knowledge, moving beyond mere assignment or coursework completion.

#### Challenges associated with mastery learning

There are several challenges associated with mastery learning. These involve: (i) *Time and Resource Constraints*: Mastery learning demands time and resources due to its need for personalized guidance and repeated practice and feedback; (ii) *Assessment Issues*: Evaluating student proficiency in certain skills and concepts can pose difficulties, with potential doubts about assessment validity and reliability; (iii) *Implementation Challenges*: Introducing a mastery learning initiative can be intricate, demanding substantial resources and specialized knowledge [25].

In conclusion, mastery learning offers a promising educational approach centered on acquiring distinct skills and knowledge. However, its success and alignment with student needs relies on meticulous planning, execution, and assessment.

### 7.2 Outcomes-Based Education

Outcome-Based Education (OBE) focuses on defining learning outcomes for students' competency in workforce tasks. Learning outcomes guide curriculum, teaching methods, and assessments to measure attainment. OBE differs from traditional models that emphasize curriculum coverage as shown in figure 4.

#### Benefits of OBE

There are several benefits of OBE. These are, (i) *Student-centered approach*: Focusing on individual learning needs enhances both engagement and understanding; (ii) *Alignment with real-world work environments*: Graduates acquire practical skills and competencies valued by employers, augmenting their employability; (iii) *Flexibility*: Providing customization choices for various learners and industries, catering to diverse educational settings.



Figure 4. Outcomes Based Education

### Drawbacks of OBE

There are several drawbacks of OBE. These are, (i) *Focus on assessment*: Potential neglect of creativity and critical thinking in pursuit of meeting specific outcomes; (ii) *Limited flexibility*: Limitations on teaching approaches and student learning preferences curtail chances for individual exploration; (iii) *High-stake testing*: Excessive focus on standardized tests can result in "teaching to the test," impeding comprehensive learning; (iv) *Inconsistent Implementation*: Inconsistent implementation across schools and regions due to insufficient support and training presents challenges.

In general, OBE holds value as an instructional approach, but it's vital to acknowledge potential drawbacks and mitigate them when possible. Balancing both learning goals and the quality of the teaching and learning process demands a comprehensive and equitable approach.

## 7.3 Competency-based education

Competency-Based Education (CBE) centers on skill and knowledge mastery, transcending conventional classroom time and coursework completion as seen in figure 5. Students are assessed through tasks or demonstrated knowledge, advancing individually with feedback until they attain mastery. Prioritizing skill growth, CBE underscores personalized learning beyond mere assignment fulfillment.

### Key features of CBE

Some key features of CBE are: (i) *Clearly Stated Learning Outcomes*: Competencies are precisely defined and communicated to students, providing a lucid understanding of their learning objectives; (ii) *Individualized Pace*: Students advance at their own speed, based on their mastery of specific competencies, allowing swifter progression for those well-versed in certain topics; (iii) *Tailored Education*: Students experience

personalized guidance for mastery while exploring areas of personal interest; (iv) *Skill and Knowledge Emphasis*: CBE prioritizes cultivating concrete skills and knowledge over conventional academic gauges like grades or coursework completion.

### Benefits of CBE

There are several benefits of CBE. These are, (i) *Enhanced Learning Outcomes*: By concentrating on specific skill and knowledge growth, CBE can yield improved learning results and superior career readiness; (ii) *Heightened Student Engagement*: CBE's personalized learning experience and exploration opportunities can amplify student involvement; (iii) *Adaptability*: CBE surpasses conventional classroom setups with its flexible learning pace and timing; (iv) *Aligned Industry Relevance*: CBE ensures students acquire skills pertinent



Figure 5. Competency based education

to their chosen careers, promoting better alignment with industry requirements.

### Challenges associated with CBE

There are several challenges associated with CBE. These are, (i) *Implementation Complexities*: Introducing CBE demands substantial resources and expertise due to its intricate nature; (ii) *Standardization Challenges*: Unifying CBE practices across diverse institutions can hinder student progress assessment and outcome comparison; (iii) *Evaluation Concerns*: Gauging student mastery of specific competencies poses difficulties, with potential apprehensions about assessment credibility and reliability; (iv) *Familiarity Gap*: Unfamiliarity among some students and parents with CBE might lead to confusion and resistance towards the approach.



## 7.4 School-based education

In traditional school-based learning, students physically attend classes where teachers provide instruction and evaluate their progress. Assessments are conducted through tests, quizzes, and assignments, and their achievements are graded based on a predetermined curriculum.

### Key features of SBE

The key features of SBE are, (i) *Organized Syllabus*: School-based education employs a structured curriculum that covers a wide array of subjects and proficiencies; (ii) *Classroom Teaching*: Instructors conduct lessons in classrooms, utilizing diverse techniques and materials; (iii) *Uniform Evaluations*: Students undergo standardized assessments to gauge their proficiency in particular subjects; (iv) *Grade-Driven Advancement*: Students advance through the curriculum based on their accomplishments and corresponding grades.

### Benefits of SBE

There are several benefits of SBE which include, (i) *Social Interaction*: School-based education fosters peer interaction, aiding in the development of essential social abilities; (ii) *Resource Availability*: Schools offer resources like textbooks, technology, and learning materials; (iii) *Proficient Teaching*: School-based education involves skilled teachers capable of providing quality instruction; (iv) *Responsibility*: School-based education upholds accountability via assessments and evaluations for students, teachers, and schools.

### Challenges associated with SBE

Several challenges associated with SBE are, (i) *Rigidity*: School-based education can lack flexibility due to set schedules and predefined curricula; (ii) *Lack of Customization*: Personalised learning to match individual student needs and interests might not be fully achievable in school-based education; (iii) *Resource Limitations*: Adequate resources and support for student success could be lacking in schools; (iv) *Teacher-Student Ratios*: Managing large class sizes can hinder teachers from offering individualized attention.

**Table 2** Comparison of different education models

Education model	Features	Benefits	Drawbacks
Mastery learning education	Mastering in specific skills and concepts	Increased student engagement, personalised learning, emphasis on skills	Resource and time constraint, assessment issues, implementation challenges

Outcome based education	Focuses on individual learning needs	Student-centred approach, alignment with real-world environment, flexibility	Negligence on creativity and critical thinking, limited flexibility, inconsistent implementation
Competency based education	Clearly stated learning outcomes, individualised pace, tailored education, skill & knowledge emphasis	Enhanced learning outcome, increased student engagement, flexible learning pace, aligned with industry relevance	Implementation complexities, standardisation challenges, evaluation concerns, familiarity gap
School based education	Organised syllabus, classroom teaching, uniform evaluation, grade-driven assessment	More social interaction, better resource availability, proficient teaching, collective responsibility	Lack of flexibility, lack of customisation, resource limitation, low teacher-student ratio

In general, conventional school-based education remains prevalent and favoured, offering numerous advantages, yet encountering obstacles in terms of adaptability, customization, and limited resources. Table 2 presents comparison of the above education models.

## 8. Some cases of implementation of IoT in organizations

IoT based education system has been implemented in different organization across the globe. A few examples of such cases are as follows.

### 8.1 University of New South Wales

The organization has introduced an IoT system to oversee resource consumption, covering water, energy, and gas. Sensors and devices are positioned strategically to collect real-time data on resource usage, which is then sent to a central management system. This technology enables the company to lower expenses and minimize waste by analyzing data to uncover inefficiencies and potential areas for enhancement.

### 8.2 Carnegie Mellon University

For monitoring and managing research lab equipment, the university devised an IoT system. Sensors affixed to tools like spectrometers, centrifuges, and microscopes gather real-time usage data, conveyed to a central system. Researchers benefit from improved study optimization and reduced downtime due to enhanced visibility into equipment availability and utilization.

### 8.3 Arizona State University

To bolster student safety, the college has implemented an IoT system. Sensors and cameras on campus collect real-time data on factors like temperature, air quality, and noise. This data analysis prompts security alerts for potential safety issues, like traffic congestion or inadequate ventilation.

## 9. Functionalities of IoT based education

A highly effective educational model integrating IoT would be characterized by innovation, interactivity, and individualized instruction tailored to each student's unique needs. Therefore, the functionalities of IoT based education are multi-dimensional (Figure 6) and are discussed as follows.

### 9.1 Smart Classrooms

Smart classrooms revolutionize the learning experience through IoT-enabled devices, optimizing students' learning efficiency. Core elements include interactive smart whiteboards, tablets, learning management systems, educational apps, and video conferencing tools.

### 9.2 Automated Lighting and sensor control

Deploying IoT sensors in classrooms detects occupancy, automatically adjusting lighting and temperature. This conserves energy and creates a tranquil, engaging, and comfortable learning environment.

### 9.3 Smart Whiteboards

These touchscreen PCs serve as comprehensive tools for teaching, discussions, and heightened classroom productivity.

### 9.4 Personalized Learning

IoT captures and evaluates data on each student's learning approach, achievements, and preferences. Educators can use this information to craft personalized lessons that cater to individual requirements.

### 9.5 Smart Learning Resources

IoT-enabled devices provide access to a wealth of digital resources like e-books, online platforms, and educational videos. These resources can be tailored to fit students' diverse learning needs and preferences.

### 9.6 Health Monitoring

IoT devices, such as smart watches and health trackers, ensure student well-being. Real-time monitoring for signs of depression, oxygen levels, and basic health metrics can alert schools, administrators, and parents.

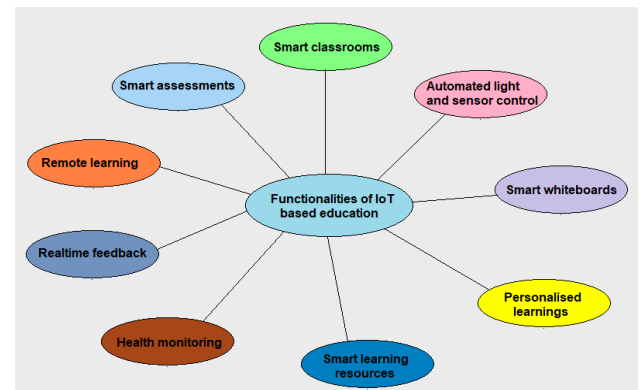


Figure 6. Functionalities of IoT based education

### 9.7 Real-Time Feedback

IoT facilitates real-time feedback for students and teachers, enabling progress tracking, identifying improvement areas, and adjusting learning strategies.

### 9.8 Remote Learning

IoT fosters remote learning, connecting students and educators across distances. Utilizing devices like smart phones, tablets, and laptops, students can engage in virtual classes, access resources, and communicate seamlessly.

## 9.9 Smart Assessments

IoT-driven smart assessments adapt to each student's learning needs, dynamically adjusting difficulty levels based on performance, offering feedback, and accommodating individual learning paces.

Therefore, the proposed IoT-based educational approach is likely to empower students with personalized, interactive, and captivating learning, enriched by diverse resources and instant feedback to attain their educational goals.

## 10. Challenges in Education 4.0

Although there are numerous advantages to using IoT in education, there are also several challenges that management, developers, and officials must consider and work to overcome. Some of the challenges that institutions may face when implementing IoT include summarised in figure 7 and discussed below.

### 10.1 High Implementation Cost and Maintenance

IoT implementation in educational institutions can be costly, requiring investments in systems, devices, software, and skilled professionals. Smaller institutions can seek affordable IoT solutions and hire a small expert team, in-house or on contract, to reduce costs. Careful planning is essential for successful IoT adoption.

### 10.2 Complexity

IoT in education is a new concept with ongoing improvements. The initial implementation may be complex for stakeholders used to traditional methods. To succeed, institutions need policies, training, and support to ease the transition and encourage IoT adoption in classrooms.

### 10.3 Accessibility and equity

To ensure equity, educational institutions should implement UDL (Universal Design for Learning) principles for accessible IoT-enabled learning. Providing equal access to IoT devices and compatibility with assistive technologies is crucial. Training and support for students and educators maximize IoT's potential. Partnerships with community organizations and seeking funding opportunities can help provide additional resources for underrepresented students. Equitable IoT implementation ensures all students benefit from its transformative power in education.

## 10.4 Integration with existing systems

Integrating IoT devices in educational institutions is challenging due to compatibility issues. Open standards and protocols enable communication and interoperability. An IoT architecture plan identifies integration points and potential issues. Training and support help staff effectively use IoT technology. Overcoming challenges requires these measures to implement IoT in the learning environment.

## 10.5 Security and privacy concerns

Data security is a critical challenge in IoT development for educational institutions. A contingency plan must be developed to mitigate data breaches and security threats. Increasing awareness through cybersecurity training for students and staff is essential to protect sensitive data and ensure the safety of IoT implementation.

## 10.6 Ethical considerations

Ethical considerations in IoT education require data privacy policies in line with regulations. Regular monitoring and evaluation of IoT device use ensure ethical practices. Promoting ethical behavior among students and staff through education and training fosters a responsible culture. This safeguards student and faculty privacy and security in IoT implementation.



**Figure 7.** Future Challenges in Education 4.0

## 10.7 Standardization

Addressing IoT interoperability challenges in education involves adopting open standards, establishing interoperability guidelines, and collaborating with industry organizations. Common frameworks and stakeholder engagement ensure seamless communication between devices, enabling efficient IoT implementation.

## 10.8 Data management

IoT technology generates vast amounts of data that present challenges for educational institutions in managing, analyzing, and utilizing it effectively. To tackle these issues, educational institutions can implement measures like data collection and analysis, data security and privacy protocols, data governance frameworks, data integration strategies, and staff training initiatives.

## 11. Conclusions

In summary, a comprehensive study is carried out on the applications of technologies such as IoT in modern education specially in Education 4.0 and the potential of these technologies to transform the education sector is analysed. The challenges faced by previous education models are analysed along with how they pave the way to the inclusion of IoT in education, leading to Education 4.0. The potential benefits of IoT in improving learning outcomes, enhancing student engagement and retention, and supporting teachers are also highlighted. Furthermore, the ethical and privacy issues linked to the utilization of these technologies are acknowledged, and potential directions for future research are highlighted. IoT has immense potential to enhance Education 4.0 by enabling data-driven decision-making, personalized learning, interactive classrooms, and improved safety. Implementation requires careful planning, investment, and privacy considerations. Despite the costs, IoT's benefits in providing accessible and convenient education make it a transformative tool for teaching and learning. Numerous educational platforms are emerging, and they leverage IoT-enabled devices to provide extended education at convenient, easy-to-use, and safe platforms for teachers and students.

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