The Internet of Things in Education: Adoption Patterns and Learning Outcomes from a Ghanaian Case Study

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ABSTRACT
Background
The Internet of Things (IoT) is increasingly transforming educational environments by connecting smart devices and enabling data-driven, interactive learning experiences. This study examines IoT adoption patterns in high school broadly - including factors influencing adoption, the impact on student learning outcomes, and the challenges to implementation - based on a case study survey of 65 students and teachers in an academic institution. Questionnaires and interviews were used to gather both quantitative and qualitative insights.

Findings
Most participants recognized IoT's potential to enhance education, with 74% agreeing that IoT can improve teaching and learning. An overwhelming 89% of students expressed interest in IoT-powered learning experiences. Participants reported improved student engagement, teaching effectiveness, and personalized learning when IoT tools were integrated. However, significant barriers to widespread IoT adoption were identified. Key challenges include financial constraints (e.g. high implementation costs and unclear return on investment), technical limitations (infrastructure and interoperability issues), and human factors such as limited IoT expertise among staff, resistance to change, and inadequate training. Notably, 66% of respondents cited cost as a major deterrent, and 69% observed that resistance to new technology hinders adoption.

Conclusion
The study underscores IoT's transformative potential to create more engaging and effective high school environments, provided that institutions address the highlighted challenges. Strategic investments in technological infrastructure, faculty training, and awareness programs are recommended to harness IoT benefits. By overcoming these barriers, high schools can leverage IoT to foster personalized, interactive learning and improve student outcomes.

Keywords
Internet of Things (IoT); High School; IoT Adoption; Learning Outcomes; Educational Technology; Smart Learning Environments.

1. INTRODUCTION
The Internet of Things, or IoT, "a global network of connected objects that can interact with the Internet", has been a game changer in the various sectors, including education. IoT is expected to completely change the ways of teaching in high-school through smart learning places. The Internet of Things (IoT), for instance, enables the collection of real-time data and automation through the integration of devices with sensors and connectivity, which can provide personalized learning experiences and increased educational efficiency [1]–[3]. This "Internet of Educational Things (IoET)" includes artifacts for advancing scholarship, pedagogy, and campus space [1]. For example, an IoT device in the classroom could recognize when a student is not paying attention, through biometric or movement sensors, and remind the teacher to recap the lesson or change the strategy being employed to capture the student's interest again [1]. In general, these transformations by IoT can create a paradigm shift in high school, where teaching can be more engaging, learning can be personalized, assessment can be improved and even managing a high school campus can become easier [2], [4].

There has been a growing research interest in the use of IoT for education in recent years. Some universities and institutions are implementing smart classrooms, which incorporate Internet of Things technologies such as projectors, smart boards, connected devices that students use, etc. to create a more interactive, student-learning focused classroom experience [5]. Research indicates that the integration of IoT in the classroom enhances the communication and dynamics of the class, making it easier for teachers to transmit knowledge, and for students to learn it more interestingly [4]. On top of that, IoT supports the safety and efficiency of campus operations. For instance, campus safety can be improved by using IoT sensors or CCTV to surveil the campus for security threats or environmental hazards and send alert precociously to students and staff [6], [7]. Rollcall can be automated through IoT- based attendance systems utilizing fingerprint scanners or biometric devices, or RFID student ID cards, resulting in high accuracy and instant notification of parents for absentees [8]. Similarly, physical equipment connected to the lab and virtual IoT labs allow students to perform experiments from a distance or to safely simulate hands-on activities, increasing access to hands-on resources [9]. These and other examples taken from the literature show a wide scope of IoT, ranging from the enhancement of routine administrative tasks to the provision of data-analysed customized learning. IoT devices can monitor the learning behavior and achievements of each student and provide data to analytics systems in order to adapt learning contents and support to each learner [10]. This aligns with the growing emphasis on data-driven personalized learning in high school.

Though IoT holds promise, its deployment has been slow in the high school sector. There are specific issues for educational institutions with larger scale IoT deployments. Previous studies show that the implementation of the IoT also involves substantial investments in infrastructure, device management, and safeguarding data [11], [12]. The expenses associated with a deployment of IoT such as purchasing devices, software licenses, or networking upgrades and maintenance can be a deterrent, particularly in developing countries or in public institutions where budgets can be tight [11], [13]. Also, adoption can be hampered by technical and organizational barriers. Some faculty and staff may not have the IoT knowhow or training to benefit from such technologies, while some educators are also reluctant to change established teaching practices [14], [15]. Plus, privacy and data protection represent other important threats when collecting students' data through IoT, as institutions have to comply with regulations and face cyber-security issues to protect this information [12]. Indeed, IoT's introduction into classrooms often brings excitement about its benefits alongside anxiety about risks and disruptions [16], [17].

2. PROBLEM STATEMENT

There remains a knowledge gap in understanding how IoT adoption specifically influences student learning outcomes and what factors most strongly facilitate or inhibit its uptake in high school [18], [19]. While many universities and institutions are piloting IoT initiatives, comprehensive studies on the educational impacts and adoption challenges are limited [20].

This research addresses that gap by investigating three core questions:

1. What factors influence the adoption of IoT applications in high school?
2. What are the impacts of IoT use on teaching and learning outcomes?
3. What challenges impede the incorporation of IoT in educational institutions?

By answering these questions, the study aims to inform strategies for successful IoT integration in academia.

Contribution

This paper presents a generalized analysis of IoT adoption in high school, based on a case study in a Ghanaian school context, but with broader implications drawn for universities, institutions and colleges. It offers empirical data on stakeholder perceptions (students and educators) of IoT's educational value and synthesizes these findings with the existing literature on IoT in education. The goal is to provide high school stakeholders - administrators, educators, and policymakers - with evidence-based insights on how to leverage IoT for improved learning outcomes while navigating the attendant challenges

3. LITERATURE REVIEW

3.1 IoT Applications and Benefits in Education

The integration of IoT in education has opened up numerous applications that enhance different facets of teaching and learning. IoT is defined as a network of physical, digital, and virtual objects endowed with sensing, processing, and communication capabilities to interact with each other and with online services [21]. In practical terms, IoT enables the creation of "smart" environments across campus - from classrooms to libraries to dormitories - where devices and systems automatically collect data and respond to users' needs. Researchers have identified several common IoT applications in high school that add value to the educational process [5], [22]:

- **Smart Classrooms**: Interconnected tools (smart boards, projectors, tablets) enhance interaction and participation. IoT improves audiovisual delivery and enables real-time engagement, fostering student-centered learning [4], [5], [23].
- **Campus Safety**: IoT surveillance systems (CCTV, motion detectors, smart alarms) enhance security by detecting threats (e.g., fires, gas leaks) and triggering rapid response protocols [6], [7].
- **Smart Attendance & Administration**: Biometric or RFID systems automate attendance, saving time and improving accuracy [4], [8], [24]. IoT asset management also reduces losses and improves resource use.
- **Virtual Labs & Remote Learning**: IoT sensors enable safe, cost-effective simulations and remote experiments. Such approaches proved valuable during COVID-19, ensuring continuity of practical learning [8][9].
- **Personalized Learning**: Data from wearables, apps, and smart notebooks allow adaptive content delivery, identifying strengths/weaknesses and suggesting tailored resources [8], [10], [25].

Studies confirm these benefits. Remya (2021) notes that IoT-enabled apps and digital texts modernize self-paced learning [21], [23], while Fernández-Batanero et al. (2024) highlight its role in boosting engagement and teaching quality [5]. IoT also aids real-time assessment and feedback, enabling more effective monitoring of performance [4], [24].

3.2 Factors Influencing IoT Adoption in High school

Technological readiness: The compelling benefits of IoT translate into adoption only when several prerequisites align. Technological readiness is foundational: institutions need reliable power, broadband, campus network capacity, and IT support to deploy and sustain IoT at scale [13]. Well-resourced universities and institutions are better positioned than those with constrained infrastructure. Because IoT spans smart buildings, energy management, and teaching spaces, a broad infrastructure upgrade is often required [20]. Gaps such as limited high-speed internet or legacy networking hardware can stall deployments and demand substantial investment and long-term planning [13].

Financial capacity: is a second determinant. Costs accrue from hardware, platforms/licenses, installation, and ongoing maintenance (support, repairs, upgrades). Under tight budgets, cost–benefit clarity becomes pivotal [11]. In Saudi high school, budget constraints especially hindered technology procurement and training [12], mirroring our case findings. Without external funding or firm institutional commitment, projects risk stalling [10], [13]. Mitigations include public–private partnerships, grants, and phased rollouts; successful adopters prioritize foundational layers (networks, security) to enable later applications [10].

Human & organizational readiness: along with technology, human and organizational aspects are also very critical. Teaching practices integrate IoT in the classroom; digital skills and attitudes are major determinants of use [5]. Low levels of training also lead to underutilization, even when infrastructure exists. Professional development should focus on building both fluency in the technical aspects and pedagogical design of activities involving IoT [1]. This sort of preparedness was missing amongst our staff, something we also experienced in our context. Buy-in from stakeholders and change management are also critical for adoption. IoT can lead to changes in workflows, or concerns about roles, or privacy [26]. Exposure to and experience with value demonstration pilots leads to improved acceptance over time, particularly if the leadership provides a message of priority and commits resources to the effort [12].

Finally, policies and regulations are consequential. Data-protection regimes (GDPR, FERPA, etc.) and explicit institutional policies regarding privacy, cybersecurity, and ethical use are reassuring implementers and provide some guardrails around implementation [12], [27]. In sum, adoption is a function of a coming together of infrastructure, finances, human readiness, and policy; all four, including technology, must be integrated in equilibrium-technology cannot be adopted without human capabilities and enabling environments to support them.

3.3 Impacts of IoT on Teaching and Learning Outcomes

Existing- and still growing as new deployments scale up-evidence suggests a number of benefical effects. As also supported in previous reviews [5], [12], the stakeholders of our study reported increased engagement as a result of interactivity (e.g., through sensor-based experiments, activities in AR, live quizzes, wearables). Real-time feedback and immersion experiences are also found to be more engaging than lectures.

Teaching effectiveness, and pedagogical innovation, also improve. The use of dashboards, auto- grading, and adaptive content allows instructors to focus on more targeted facilitation and on- the- spot remediation [7], [23]. Analysis of use (e.g., what parts get replayed, what items score low) provides data from which instruction can be modified, and it builds over time to create a more effective classroom in terms of performance.

IoT supports personalized learning via adaptive pathways that fit individual pace and needs; analyses of IoT-derived learning data have enabled targeted interventions and improved outcomes in pilots [8], [10]. Our results similarly indicate broad agreement that IoT aids customization, aligning with views of IoT as enabling sustainable, evolving content responsive to learner feedback [1].

IoT further strengthens collaboration and communication (response systems, remote/virtual labs, connected platforms), extending interaction beyond classroom boundaries and supporting peer learning [26]. While rigorous, large-scale achievement studies remain limited, early cases report improved satisfaction, participation, and project quality, all precursors to performance gains [12]. In sum, when aligned with pedagogy, IoT advances engagement, personalization, and collaboration, laying the groundwork for better outcomes

3.4 Challenges to IoT Integration in High school

Realizing benefits requires addressing technological, financial, and human obstacles [26]. Cost is a leading constraint: institutions face significant upfront spending (devices, platforms, infrastructure) and sustained outlays for maintenance and data management [11]. With limited budgets, many initiatives stall at pilot stage absent sustainable funding [8].

Infrastructure shortfalls-insufficient bandwidth, unstable power, outdated IT-limit reliability and scalability, particularly in developing or rural contexts, and can widen equity gaps between well-funded and under-resourced universities [10], [13]. Security hardening adds further complexity and expense.

Human factors include resistance to change among faculty/administrators, concerns about role disruption or surveillance, and skills gaps in both IT and pedagogy for IoT [5], [25], [28]. Effective responses combine participatory planning, transparent data-use policies, hands-on training, and communities of practice; leadership endorsement is critical [1], [5], [12].

Privacy and security remain core risks, given sensitive educational and potential biometric data. Compliance (e.g., GDPR, COPPA/FERPA) requires robust governance, encryption, access controls, and specialized expertise, which can slow or reshape implementations [8], [12]. Notably, our pilot context reported lower perceived risk-likely due to scope limits-yet broader rollouts cannot ignore security without eroding trust.

A final barrier is awareness and mindset: limited understanding of IoT's concrete educational value suppresses demand and adoption. Pilots, demonstrations, and visible success stories help shift perceptions and build momentum [7][26]. **Error! Reference source not found.** summarizes these challenges and their nature.

Table 1. Summary of major challenges in IoT adoption for education, as identified by literature

Papers	Challenge Category	Specific Challenges
[8], [22]	Financial & Infrastructure	High upfront costs (devices, software, etc.)
[8]		Ongoing costs (maintenance, upgrades)
[10]		Insufficient IT infrastructure (network, power)
[10]		Funding limitations for education sector
[5];	Human & Organizational	Resistance to change among staff or stakeholders
[25]		Lack of IoT expertise in IT staff
[1]		Need for teacher training and professional development
Present study findings		Low awareness of IoT benefits (value not understood)
[8]	Data Security & Privacy	Risk of data breaches or cyberattacks
[10]		Privacy concerns with student data collection
[8]		Regulatory compliance (GDPR, etc.) adds complexity

4. METHODOLOGY

4.1 Research Design and Approach

This study used a descriptive case study with an action research framework at a single pilot institution to implement an IoT-enabled instructional intervention and observe outcomes. The design was cross-sectional (single time-point survey) with pre/post comparison of learning outcomes to gauge change. Action research was chosen to jointly drive local improvement and contribute generalizable insights. Data collection was primarily quantitative (structured questionnaires) with qualitative interviews and observations to provide a mixed-methods perspective. Data collection proceeded in three sequential stages: (i) baseline survey of awareness and readiness, (ii) IoT intervention within the ICT curriculum, and (iii) post-intervention survey and interviews. This order clarifies the temporal structure of the study without implying repeated measurement beyond one term.

4.2 Study Setting and Participants

The case was conducted at a secondary-level institution (pseudonym: Nana Baadu Junior High School, Ghana) representing part of the high school pipeline. The school expressed readiness to pilot curricular technology. The target sample was N=65 (students and teachers). Participant age distribution appears in **Error! Reference source not found.**; the largest academic group was JHS Three, and teachers constituted ~9% of respondents (**Error! Reference source not found.**). The student sample was selected via simple random sampling; whole classes were randomly chosen to approximate individual randomization given heterogeneous composition. All teachers of the sampled classes were invited to capture diverse subject expertise. Institutional approval was obtained before data collection, and participation was voluntary. The study therefore adhered to standard ethical practice for classroom-based educational research. Although modest, the sample was appropriate for exploratory work and sought representativeness across grades, gender, and academic streams.

Table 2. Age Distribution of Participants at Nana Baadu Junior High School (N = 65)

Age Group	Male	Female	Total
9-14 years	20	8	28
15-17 years	16	12	28
Above 18	2	1	3
Total	38	21	59

(Note: The participant numbers above reflect those who responded to the survey instruments; initially 65 were targeted, with 56 student responses and 9 teacher responses obtained, giving a 100% response rate from the sample.)

Table 3. Level of Study Distribution of Participants (N = 65)

Level/Role	Frequency	Percentage
J.H.S One (1)	13	20%
J.H.S Two (2)	18	28%
J.H.S Three (3)	28	43%
Teachers	6	9%
Total	65	100%

The sampling technique employed was simple random sampling for students, ensuring each student in the population had an equal chance of selection. For practical implementation, entire classes were randomly chosen to participate in the survey, under the assumption that class composition is heterogeneous enough to approximate random selection of individuals. All teachers who taught those classes were invited to participate, capturing a range of subject expertise. The sample, while not large, was deemed sufficient for an exploratory study of this nature, and efforts were made to ensure it was representative of the school's demographics (covering all three grade levels at the junior secondary stage, and including both genders and multiple academic streams).

4.3 IoT Intervention and Instruments

An IoT-based educational intervention was designed and implemented as part of the methodology to observe its effects on teaching and learning. This intervention involved integrating IoT-supported instructional technologies into the school's ICT (Information and Communication Technology) curriculum over one term. Specifically, the researcher developed a multimedia tutorial system that leveraged IoT concepts - for example, a set of lessons on basic programming and sensor data that were delivered through an interactive e-learning platform accessible via tablets, along with physical IoT kits (Arduino-based sensors) for hands-on experiments. This design drew from constructivist teaching principles, aiming to engage students actively with technology. The intervention addressed some previously observed challenges in students' ICT learning (low engagement and poor performance) by introducing new tools and content (as noted by the teacher-researcher during internship at the school). Key components of the intervention included:

- **IoT-Enhanced Lessons:** Regular ICT lessons were augmented with IoT examples (e.g., a lesson on networks included demonstrating sensor nodes transmitting data to the cloud). Students interacted with these IoT devices directly during class.
- **Project-Based Assignments:** Students were assigned a simple IoT project (such as using a temperature sensor to log classroom temperature over a week) to encourage exploration and problem-solving using IoT.
- **Teacher Training:** Before the intervention, brief training sessions were conducted for teachers on how to use the IoT kits and the multimedia tutorial, to improve confidence and smooth integration into lessons.

Instruments

1. **Structured questionnaire** (paper-based due to connectivity), expert-reviewed and piloted, using mainly 5-point Likert items plus MCQ and one open-ended prompt. Sections mapped to research questions:
    - **A** IoT knowledge/perception;
    - **B** institutional readiness (resources, infrastructure, leadership);
    - **C** interest/digital literacy (yes/no; self-ratings);
    - **D** educational impact (engagement, effectiveness, personalization, pedagogy);
    - **E** application use (e.g., engagement tools, interactive e-learning);
    - **F** challenges-technological, financial, human, privacy/security-with an open-ended item for nuanced barriers.
2. **Semi-structured interviews** (n=8; 6 students, 2 teachers; 20–30 minutes; recorded with consent) exploring experiences, perceived benefits,

difficulties, adoption enablers, and teacher observations pre/post intervention.

Classroom observations documenting attendance, participation, technical glitches, and integration fidelity to triangulate self-reports.

4.4 Data Analysis

Quantitative: Likert items were coded 5=Strongly Agree … 1=Strongly Disagree. Item-level results are summarized by descriptives (frequencies; % agree vs. disagree). Items were collapsed (Agree + Strongly Agree) to present composite perceptions of benefits and challenges (i.e. '74% agreed IoT can improve education').

Quantitative: responses to open-ended questions and interview transcripts were analyzed thematically for repeated comments and suggestions which included: increased engagement/interest; sporadic access to device/ internet; understanding concepts better with hands-on IoT; and requests for more training/devices. Examples of quotes are provided in the Discussion to illustrate quantitative trends.

Pre/post-performance: Comparison of ICT test averages (prior term vs. intervention term) suggested a ~5-percentage-point improvement; given small sample and no control group, this is indicative only (no inferential tests).

Reliability: Cronbach's alpha indicated acceptable/good internal consistency: 0.78 for the Educational Impact scale (3 items) and 0.82 for the Challenges scale (multi-item).

Ethics and rigor: Institutional permission and informed consent were obtained; anonymity and voluntariness were assured. Analyses were manually cross-verified, and findings were reported back to school leadership to inform local improvement.

5. RESULTS

Findings are organized by the three research questions (RQ1–RQ3) and integrate questionnaire results with interview/observation insights for triangulation.

5.1 A. Factors Influencing IoT Adoption (RQ1)

IoT knowledge and perceptions: Knowledge was mixed: 66% reported *average or above* (levels 3–5) and 34% *limited/none* (0–2); the modal rating was level 3 (29%) (Table 2). Teachers generally rated themselves higher. Perceptions were strongly positive: 74% agreed/strongly agreed that IoT can significantly improve education, with interviews describing IoT as making learning "more interesting" via practical examples.

Table 2: Knowledge Levels of Participants Regarding IoT (N = 65)

Knowledge Level (0-5)	Frequency	Percentage
0	4	6%
1	6	9%
2	12	18%
3	19	29%
4	10	15%
5	14	22%
Total	65	100%

Institutional readiness & cost–benefit: Readiness was moderate: 55% agreed the institution is prepared; 26% neutral; ~18% disagreed. Interviews cited partial Wi-Fi/device availability and budget limitations, consistent with developing-context constraints. On cost–benefit, 54% agreed benefits outweigh costs; 28% neutral; ~16% disagreed.

Institutional Factors: The survey probed three specific institutional factors through Likert items, essentially statements phrased negatively or positively about the school's situation:

- **Resources:** 54% agreed resources are insufficient (barrier), 23% disagreed; 23% neutral.
- **Infrastructure:** 46% agreed IT infrastructure supports IoT, 48% disagreed, 6% neutral.
- **Leadership:** 37% agreed support is strong; 29% neutral; 34% disagreed.
  Overall, finances are the clearest constraint; infrastructure and leadership show mixed signals.

Interest & digital literacy: Interest is high: 89% of students want IoT-related learning (Figure 1). Self-rated digital literacy: 49% Yes, 32% Rarely, 17% No, 2% Unsure-i.e., 81% report at least some literacy to build on (training needed for the 17%). Table 3 below shows the Perceptions of IoT in Education.

Table 3: Perceptions of IoT in Education (N = 65)

Response	IoT improves education	Institution prepared to adopt	Benefits outweigh costs
Strongly agree	20 (31%)	13 (20%)	16 (25%)
Agree	28 (43%)	23 (35%)	19 (29%)
Neutral	10 (15%)	17 (26%)	18 (28%)
Disagree	3 (5%)	7 (11%)	7 (11%)
Strongly disagree	4 (6%)	5 (7%)	3 (5%)
Total	65 (100%)	65 (100%)	65 (100%)

From these institutional factors, the clearest concern is financial resources - a majority explicitly pointed to that as a limiting factor. Infrastructure and leadership support are less clear-cut but show that improvements are needed in both realms to strengthen adoption potential.

Interest and Digital Literacy: A very encouraging finding for adoption prospects is the high level of interest among students in IoT-related learning. When asked a yes/no question *"Are you interested in IoT-related learning experiences?"*, an overwhelming 89% of students responded "Yes". Only 3% said "No," with the remainder either "Not sure" (6%) or a very small 2% indicating some qualified interest (the questionnaire had options like "Maybe" or "Not really," which were rarely selected). This result (illustrated in Figure 1) shows a strong latent demand: students are eager to have IoT integrated into their education. It aligns with global trends of tech-savvy youth who are interested in emerging technologies. For the institution, this implies that any IoT programs introduced would likely be met with enthusiasm rather than apathy from the student body - a positive sign for user adoption.

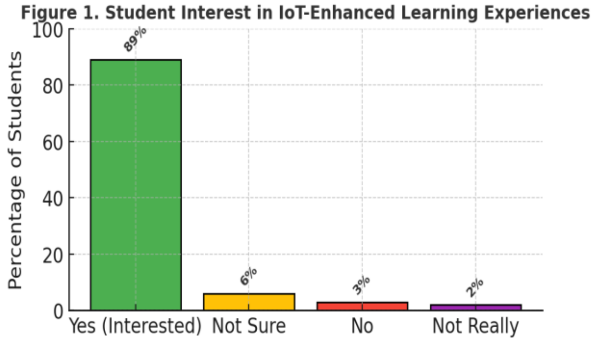

Figure 1: Student Interest in IoT-Enhanced Learning Experiences - (Based on survey question: "Are you interested in IoT-related learning experiences?")

Interpretation (RQ1): Adoption prospects are favorable (high interest, positive perceptions), but uneven knowledge and resource constraints temper readiness; efforts should pair awareness/training with infrastructure and budgeting.

5.2 Impacts of IoT on Learning and Teaching (RQ2)

Survey and intervention data indicate positive effects on engagement, teaching effectiveness, and personalization. Specifically, 63% agreed IoT improved engagement (28% strongly, 35% agree; 10% disagreed); 65% agreed overall teaching/learning effectiveness improved (20% strongly, 45% agree; ~14% disagreed; ~23% neutral); and 60% agreed IoT supported personalized learning (15% strongly, 45% agree; 23% neutral; 17% disagreed). Interviews reported more interactive, "fun" lessons, clearer theory–practice links (e.g., live sensor data), a broader method mix, and self-paced exploration via projects.

Diversification of pedagogy was widely recognized: 75% agreed IoT introduced new teaching methods (35% strongly, 40% agree; 10% disagreed). Table 4 shows the Perceived educational impacts of IoT (engagement, teaching effectiveness, personalization)

Table 4: Perceived educational impacts of IoT (engagement, teaching effectiveness, personalization)

Response	Engagement & motivation	Teaching effectiveness	Personalized learning
Strongly agree	18 (28%)	13 (20%)	10 (15%)
Agree	23 (35%)	29 (45%)	29 (45%)
Neutral	18 (28%)	15 (23%)	15 (23%)
Disagree	3 (5%)	7 (11%)	5 (8%)
Strongly disagree	3 (5%)	2 (3%)	6 (9%)
Total	65 (100%)	65 (100%)	65 (100%)

Interpretation (RQ2): IoT is associated with higher engagement, broader pedagogical repertoire, and movement toward personalization-precursors to improved learning outcomes.

Which IoT tools had the greatest academic impact? PowerPoint-based smart presentations ranked first (62%), followed by student engagement tools (29%) and specialized e-learning (18%) (Figure 2). This underscores a pragmatic insight: augment familiar tools first (e.g., clickers, live IoT data in slides), then scale to advanced platforms. One student noted that phone-based live quizzes embedded in slides made classes "more engaging."

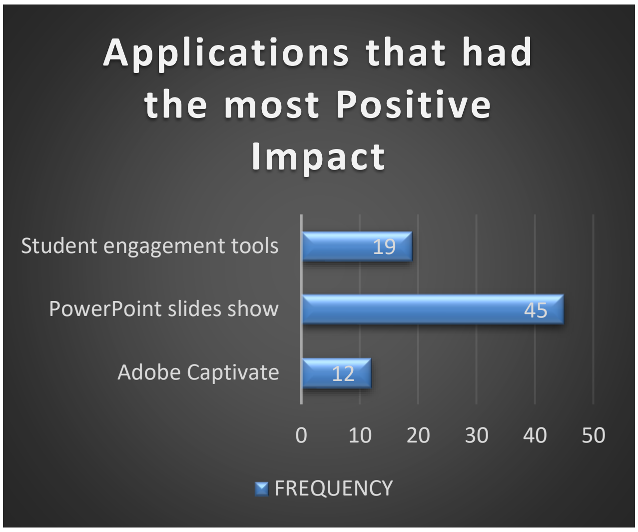

Figure 2: IoT Applications with Most Positive Academic Impact. PowerPoint (62%) > engagement platforms (29%) > specialized multimedia (18%)

Overall impact was strongly positive: 95% viewed IoT's effect on students as positive (Figure 2); item breakdown showed 28% strongly agree, 34% agree (= 62% explicit positive), 28% neutral, and ~10% disagree (3% disagree, 7% strongly disagree). Qualitative feedback highlighted greater confidence, curiosity, participation, teamwork, and instances of quiet students taking leadership roles. Figure 3 below shows the Overall Perception of IoT's Impact on Students

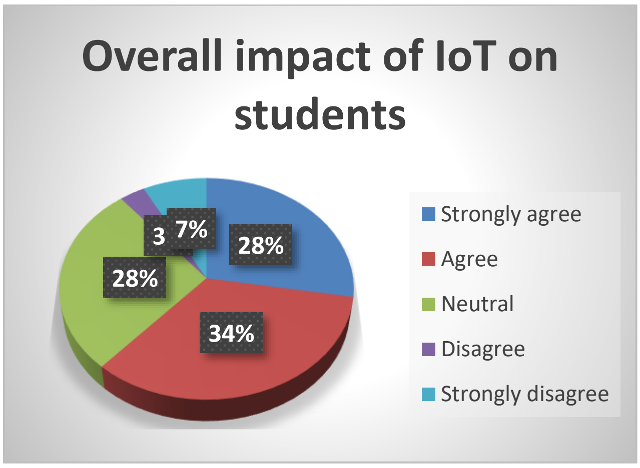

Figure 3: Overall Perception of IoT's Impact on Students

N.B: (95% of respondents indicated IoT has an overall positive impact on students, with only 5% perceiving it negatively or not at all.)

Interpretation (RQ2): IoT coincided with higher engagement, a richer pedagogical repertoire, and movement toward improved effectiveness within a more interactive, personalized environment; although long-term performance was not formally tested, participation/motivation gains and a modest test-score uptick suggest a favorable trajectory when implementation remains pedagogy-aligned.

5.3 Challenges in Incorporating IoT (RQ3)

The study identified several challenges that currently hinder the broader adoption of IoT in the educational context, echoing many of the issues highlighted in the literature review. These challenges can be grouped into technological, financial, and human factors, each of which was assessed via specific survey items and interview questions.

Technological Challenges

Only 24% saw data security/privacy as a significant challenge (6% strongly, 18% agree; 43% disagreed; 32% neutral), likely reflecting early, mostly offline use and limited awareness; proactive safeguards are still warranted. Interoperability concerns drew 33% agreement (44% disagreed; ~23% neutral), with pre-configured kits minimizing issues; risks may rise at scale (Table 5).

Table 5: Technological Challenges in IoT Adoption (N = 65)

Response	Data security & privacy	Interoperability
Strongly agree	4 (6%)	7 (11%)
Agree	12 (18%)	14 (22%)
Neutral	21 (32%)	15 (23%)
Disagree	18 (28%)	21 (32%)
Strongly disagree	10 (15%)	8 (12%)
Total	65 (100%)	65 (100%)

In summary, technical issues (security and interoperability) were not top-of-mind barriers for our participants at this stage. Only a minority highlighted them, suggesting that more immediate, tangible challenges overshadowed these considerations.

Financial Challenges

The cost of IoT implementation and the clarity of return on investment (ROI) for IoT projects. These turned out to be among the most significant challenges identified:

- *High Implementation Cost:* was salient (66% agree; 40% strongly, 26% agree; ~20% disagree) and ROI was often unclear (52% agree; 20% strongly, 32% agree; 17% disagree; ~31% neutral), echoing interviews about tight budgets and device sharing (Figure 4).

Human (Personnel) Challenges

Three major human factor challenges were surveyed, each corresponding to a potential barrier discussed earlier:

- *Lack of Staff Expertise:* 62% of respondents agreed that a lack of IoT expertise among staff is a challenge to adoption. (22% strongly, 40% agree). Only ~14% disagreed, with 25% neutral. This indicates a broad recognition that teachers and IT staff may not currently have all the skills needed to implement IoT effectively. Students likely notice when teachers are not completely comfortable with new tech. In our intervention, teachers managed with the training given, but a couple of tech-savvy teachers led the way; others admitted they relied on peer support. This agreement suggests that professional development is urgently needed if IoT were to scale up. The fact that a quarter were neutral perhaps includes some students not sure of their teachers' capabilities, but the majority opinion is clear: building *human capacity* is essential. This aligns with literature citing teacher digital competence as a key factor.

- *Resistance to Change:* 69% agreed that resistance to change among faculty or staff is hindering IoT adoption. This was one of the strongest consensuses (26% strongly, 43% agree). Only ~15% disagreed, rest neutral. It appears many participants believe that some educators are hesitant or slow to embrace IoT and innovative practices. This can stem from comfort with traditional methods, fear of technology, or skepticism about its benefits. In our context, while the ICT teacher was enthusiastic, some older teachers in other subjects were reportedly less involved and possibly skeptical. Students observed that only certain classes used IoT, implying not all teachers opted in. The strong agreement here emphasizes that mindset and openness are as big a barrier as any technical issue. Changing this will require efforts like awareness building, demonstrating successful use cases, and administrative encouragement.

- *Inadequate Training Opportunities:* 58% agreed that faculty/staff training on IoT is inadequate so far. (20% strongly, 38% agree). About 17% disagreed and 15% neutral. This ties closely with the lack of expertise, but specifically points to insufficient formal training provided. Indeed, aside from the brief training given for this study, the school had not conducted any IoT-specific training. Teachers are essentially self-taught or learning on the go. The respondents (likely teachers among them) clearly feel more training is required. Perhaps the slightly lower agreement % compared to expertise (62%) is because some consider "lack of expertise" a problem but may hope to self-educate, whereas "lack of training" highlights that the institution has not offered much - and most acknowledge that gap. Nevertheless, nearly 6 in 10 explicitly see it as a problem, reinforcing the call for professional development programs on IoT usage. The Table 6 below shows the Human challenges in IoT adoption (lack of expertise, resistance to change, inadequate training)

Table 6: Human challenges in IoT adoption (lack of expertise, resistance to change, inadequate training)

Response	Lack of IoT expertise	Resistance to change	Inadequate training
Strongly agree	14 (22%)	17 (26%)	13 (20%)
Agree	26 (40%)	28 (43%)	25 (38%)
Neutral	16 (25%)	10 (15%)	16 (25%)
Disagree	5 (8%)	8 (12%)	9 (14%)
Strongly disagree	4 (6%)	2 (3%)	2 (3%)
Total	65 (100%)	65 (100%)	65 (100%)

The survey also included an open-ended query about the main challenge the school faces regarding IoT. The most frequent answer, given by almost half of respondents, was *"lack of awareness about IoT benefits."* In fact, 49% mentioned poor awareness or understanding as the main issue, topping even funding, which came second (29% cited difficulty in changing existing processes like traditional attendance, essentially resistance to change, as their main issue). Privacy concerns were a distant third (11%). This finding is telling: even though structured items highlight cost, etc., when asked openly, most people wrote about not enough knowledge or awareness. It suggests they feel if people (peers, faculty, admin) *truly understood IoT's value*, other challenges could be overcome. It also reflects perhaps that many students themselves only discovered IoT's usefulness during the intervention - prior to that, they simply weren't aware of what IoT could do. Awareness ties into human factors and is somewhat upstream: without awareness, there is likely to be resistance, lack of demand, and no push to allocate resources. So, the primacy of "lack of awareness of IoT benefits" in open responses underscores an important point: advocacy and education about

IoT's potential is needed among the school community to drive adoption.

Bringing these challenge findings together: The most acute obstacles identified are financial constraints and human factors (expertise, openness, training). Technological issues like security and interoperability, while acknowledged, were not the main worry at this stage - possibly because they have not been encountered at scale yet. Figure 4 provides a consolidated view of the challenge landscape as perceived by respondents (using agreement levels as an indicator for severity).

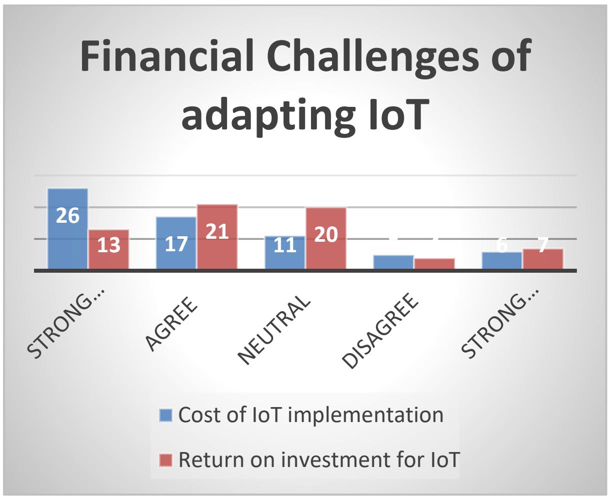

Figure 4: Summary of Key IoT Adoption Challenges (by percentage of respondents identifying them)

N.B: Financial (cost) and human factors (resistance, lack of expertise) rank highest, while technical factors (privacy, interoperability) rank lower in this context.

As shown in Figure 5, the most acute obstacles involve financial and human-capacity issues, whereas technical concerns are less pronounced at this stage of deployment.

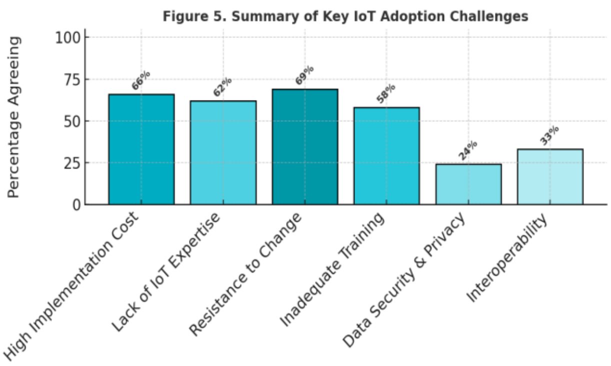

Figure 5: Summary of Key IoT Adoption Challenges

Percentages represent Agree + Strongly Agree responses (N = 65). High implementation cost (66 %), resistance to change (69 %), and lack of IoT expertise (62 %) predominate, while inadequate training (58 %), data security & privacy (24 %), and interoperability (33 %) rank lower in severity

Interpretation (RQ3): The primary constraints are financial and human (skills, openness, training, awareness); technical issues appear secondary at this stage but will require governance as deployments scale.

6. DISCUSSION

Overall, the study indicates strong optimism about IoT's educational value alongside clear impediments that institutions must address. Perceived benefits align with prior work portraying IoT as pedagogically transformative: participants widely reported gains in engagement and teaching quality, echoing Fernández-Batanero et al. (2024) [5]. Our figure that 95% viewed IoT's overall impact as positive reinforces this literature and shows that even familiar tools (e.g., PowerPoint augmented with quizzes or live data) can meaningfully elevate classroom interactivity. In parallel, 60% perceived greater personalization, consistent with claims that IoT's data streams support adaptive, learner-centered instruction [8]. As Kolhe (2022) notes, such analytics help tailor support; our participants similarly described self-paced exploration and interest-driven extensions [8].

Adoption patterns in this case also mirror existing models. Ali et al. (2023) emphasize usability, technical support, and user competence as primary drivers, with privacy and infrastructure perceived as less determinative [12]. Our findings converge: training/competence and support surfaced as critical, whereas privacy/security drew limited concern from users (though it remains objectively important). These results suggest that human-centric and organizational variables should be foregrounded in education-specific adoption frameworks, in line with work highlighting environmental and personal factors. Fernández-Batanero et al. (2024) further stress teacher attitudes and digital competence [5]; our data quantifies this with 69% citing resistance to change and 62% lack of staff expertise-evidence that professional development and change management are not ancillary but central to successful integration.

For resource-constrained settings like our Ghanaian case, the dominant barrier is cost. With 66% flagging high implementation cost and 52% uncertain about ROI, institutions should prioritize cost-effective, high-impact steps: augment existing tools (e.g., connected slides, clickers/phones), leverage BYOD, and phase investments while rigorously evaluating outcomes to build a business case. Partnerships with government, NGOs, and industry can offset costs and accelerate capacity building, as recommended in prior work. Because 49% identified lack of awareness as the principal challenge, targeted communication-demonstrations, showcases, and clear institutional vision-should accompany investment to convert enthusiasm into sustained adoption.

Human-factor obstacles warrant structured responses. Formal PD (workshops on IoT pedagogy, mentoring, recognition for innovators) can raise competence and create local champions. Resistance often reflects uncertainty about workload or efficacy; sharing internal success stories and gradually onboarding hesitant faculty can shift attitudes, as evidenced by interviewees who changed views after observing student engagement.

Although participants downplayed security, institutions should not. As deployments scale, vulnerabilities and regulatory obligations grow. Early policy frameworks (acceptable use, data protection) and technical safeguards (segmented networks, device management, encryption) are essential, aligning with best-practice guidance [12]. User neutrality on security should be read as a risk signal, not a license to defer safeguards.

Our single-site, early-stage snapshot is most applicable to institutions at the pilot phase. Later-stage adopters may face different bottlenecks (e.g., platform integration, data governance at scale). Limitations include modest sample size (N=65), single-institution context, and potential novelty effects; nonetheless, the patterns cohere with broader reviews (e.g., Saeed et al., 2021) noting persistent gaps in standards and faculty preparation [11]. Looking ahead, addressing financial and human constraints positions campuses to evolve toward smart, data-informed environments where IoT enriches instruction, extends learning beyond classrooms, and becomes an expected feature for incoming cohorts.

7. CONCLUSION

This study examined IoT integration in a higher-education setting, focusing on adoption patterns, learning impacts, and barriers. Across students and teachers in a Ghanaian institution, the evidence points to substantial educational benefits alongside practical constraints that shape readiness and scale-up.

Perceived benefits were strong: 95% rated IoT's overall effect on students as positive, with consistent reports of higher engagement, improved teaching effectiveness, and greater personalization (as detailed in the Results; see Figures 5–6; Tables 3–5). Notably, even familiar tools (e.g., PowerPoint augmented with quizzes or live data) yielded immediate gains, underscoring that aligning IoT with existing pedagogy can be highly effective. These patterns likely generalize to many higher-education contexts, where digitally fluent learners respond to connected, hands-on instruction.

Adoption readiness, however, was uneven. While student enthusiasm was high, institutional preparedness was mixed, with many respondents questioning whether resources and infrastructure were sufficient and leadership prioritization adequate. This reflects a common trajectory: pilot successes driven by early adopters followed by the challenge of institution-wide scaling, which depends on closing resource gaps and building organizational capacity.

Barriers clustered as financial, technical, and human. Financial constraints were paramount-66% flagged high implementation cost-while ROI remained uncertain for many. Technical issues (data security, privacy, interoperability) were not seen as immediate deal-breakers by participants but remain critical for sustainable, trusted systems. Human factors were substantial: lack of staff expertise, inadequate training, and resistance to change were widely cited, highlighting the need for upskilling and culture change.

In light of these conclusions, institutions should pursue strategic, phased investment (including partnerships and grants), sustained faculty development, and proactive awareness and change-management efforts (e.g., sharing success cases to build buy-in). Pilots should be evaluated rigorously to clarify ROI and guide scaling, while IT and security frameworks-covering network upgrades, device/data management, and privacy policies-must mature in parallel.

Taken together, the promise of IoT in high school is tangible: when implemented thoughtfully and supported by investment in people, infrastructure, and governance, IoT can deliver more engaging, effective, and personalized learning environments. By addressing the financial, technical, and human constraints identified here through targeted planning and inclusive capacity building, universities can translate early gains into durable, scalable impact for learners and educators alike.

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