WIP: Impact of Wi-Fi 6E Deployment on Student Engagement and Learning Outcomes in Hybrid and Digital Learning Environments at HBCUs.

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Abstract

The rapid expansion of hybrid and digitally mediated instruction has intensified universities' reliance on campus wireless networks to support teaching, learning, and academic engagement. Recent advances in wireless standards, such as Wi-Fi 6E, promise higher throughput, reduced latency, and improved performance in dense learning environments. However, empirical evidence linking network infrastructure upgrades to student engagement and learning outcomes remains limited, particularly within engineering education and Historically Black College and University (HBCU) contexts.

This work-in-progress examines a campus-wide Wi-Fi 6E deployment at an HBCU and investigates how students perceive network quality following the upgrade and how those perceptions relate to technology acceptance, digital engagement, and perceived learning experiences in hybrid and digital learning environments. Guided by the Technology Acceptance Model (TAM), the Unified Theory of Acceptance and Use of Technology (UTAUT), the Community of Inquiry (CoI) framework, and constructivist learning theory, the study adopts a mixed-methods, quasi-experimental design.

Data collection is ongoing. Preliminary findings reported here draw from a post-deployment student survey capturing perceived network quality, facilitating conditions, engagement, and perceived learning quality. Planned analyses will integrate pre- and post-deployment Wi-Fi telemetry (throughput, latency, jitter, and client distribution), learning management system (LMS) engagement data, and a matched comparison building using a difference-in-differences approach with course and time fixed effects.

Early survey results suggest improved perceptions of network speed and reliability and higher reported ease of participation in digital learning activities following the upgrade. However, deeper indicators of cognitive engagement show more modest gains, reinforcing prior research suggesting that infrastructure improvements primarily reduce barriers to participation rather than directly producing learning gains.

This WIP establishes a theoretically grounded and methodologically rigorous framework for evaluating how wireless infrastructure functions as an enabling, but insufficient component of hybrid learning environments. The final study will offer evidence-based guidance for engineering educators and administrators seeking to align campus network investments with equitable and pedagogically effective learning environments.

Keywords: Wi-Fi 6E, student engagement, hybrid learning, digital learning, technology acceptance, Community of Inquiry, HBCU

Introduction

Hybrid and digitally mediated learning environments are now central to higher education. Engineering courses increasingly rely on learning management systems, simulation software, video conferencing, and cloud-based collaboration tools. Consequently, campus wireless networks have become core educational infrastructure rather than background utilities. Prior research shows that access to digital resources shapes student engagement, especially in technology-enhanced learning environments [7], [8].

Wi-Fi 6E extends wireless operation into the 6 GHz band, offering wider channels, reduced interference, and lower latency, features especially valuable in dense academic spaces [10]. Universities often justify such upgrades as necessary for modern pedagogy. However, technical improvements do not automatically translate into improved engagement or learning outcomes. Studies of campus Wi-Fi usage show that connectivity supports both academic and non-academic activity, complicating assumptions that better networks directly improve learning [3], [11].

This issue is particularly salient at HBCUs, where campus Wi-Fi may serve as students' most reliable access to digital learning tools. In such contexts, wireless infrastructure becomes an equity-relevant component of the learning environment. Yet few studies explicitly connect infrastructure conditions to engagement and learning using theoretically grounded models.

This WIP addresses this gap by examining a Wi-Fi 6E deployment at an HBCU and exploring how perceived network quality relates to technology acceptance, engagement, and perceived learning in hybrid and digital learning environments. The paper reports early survey findings and outlines a rigorous design for integrating telemetry and LMS data in later analyses.

Research Questions

This study is guided by the following research questions, which are intentionally broad to accommodate planned future analyses:

RQ1: How do students perceive changes in campus Wi-Fi quality following a Wi-Fi 6E deployment?

RQ2: How are students' perceptions of network quality associated with technology acceptance and facilitating conditions for hybrid and digital learning tools?

RQ3: How do perceived network quality and technology acceptance relate to students' self-reported behavioral and cognitive engagement in hybrid and digital learning environments?

RQ4: How do changes in objective network performance metrics (e.g., throughput, latency, jitter, client distribution) correspond with changes in LMS engagement patterns and student-reported engagement?

RQ5: To what extent do engagement indicators reflect the relationship between network performance and perceived learning quality over time?

RQ1–RQ3 are addressed in the present WIP through survey data, while RQ4–RQ5 will be examined in the completed study through integrated telemetry and LMS analyses.

Conceptual and Theoretical Framework

This study integrates multiple theoretical perspectives such as Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), Community of Inquiry (CoI), and constructivist learning theory. TAM emphasizes perceived usefulness and ease of use as predictors of technology adoption, both influenced by perceived network quality. UTAUT highlights facilitating conditions of which stable connectivity is central in hybrid learning [2].

The Community of Inquiry framework conceptualizes meaningful learning as the interaction of cognitive, social, and teaching presence, all of which depends on reliable technological mediation [12]. Constructivist theory positions learning as active engagement within supportive environments.

Together, these frameworks suggest a layered model as shown in Figure 1 in which wireless infrastructure influences network performance, which shapes technology acceptance and facilitating conditions, leading to student engagement and, ultimately, learning outcomes, as illustrated in Figure 1. Wireless infrastructure is therefore positioned as a necessary but insufficient component of the learning environment.

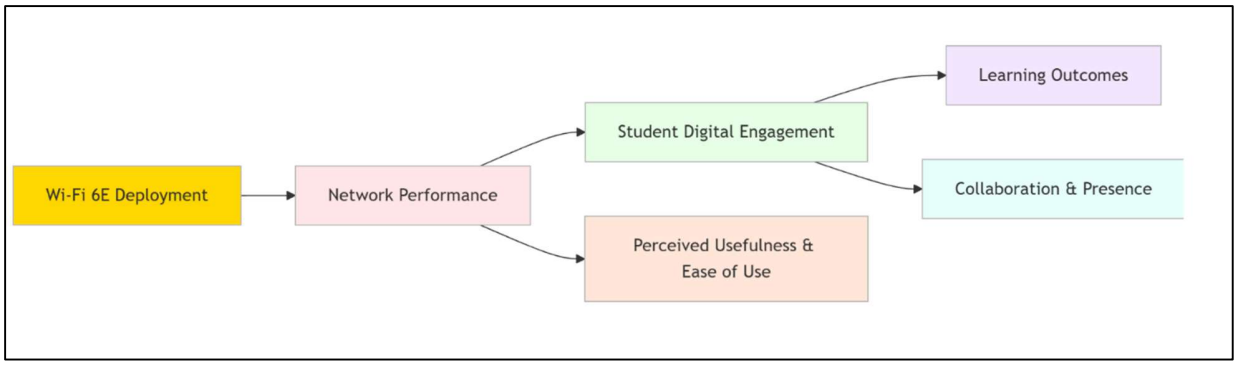

Figure 1: Relationship between Wi-Fi deployment and learning outcomes

Campus Wireless Networks and Student Academic Activity

Studies of campus Wi-Fi show that connectivity is embedded in students' academic routines but does not inherently improve performance [3], [11]. Technical reports on Wi-Fi 6E emphasize performance gains but rarely examine educational outcomes [10].

Research on technology-enhanced learning shows that facilitating conditions are associated with engagement and satisfaction, but deeper learning gains are inconsistent [2], [9]. Engagement research distinguishes between behavioral and cognitive engagement, with digital tools strongly influencing behavioral engagement [5], [12]. Few studies integrate objective infrastructure data with theoretically grounded engagement models, especially within HBCU contexts motivating the present study.

Methodology

This study uses a mixed-methods, quasi-experimental design to examine how a campus-wide Wi-Fi 6E deployment influences student engagement and perceived learning experiences. The design integrates self-reported student perceptions with planned objective measures of network performance and learning management system (LMS) engagement. The analytic strategy is guided by a difference-in-differences (DiD) framework that compares pre- and post-deployment conditions in the upgraded space relative to a matched comparison building. As a work-in-progress, this paper reports preliminary findings from a post-deployment student survey and details the full research pipeline through which additional data sources will be incorporated.

Participants and Data Collection

An anonymous online survey was administered after deployment. QR codes were displayed in the student center. Eighty-two valid responses were collected from undergraduates, graduate students, and staff.

Instrumentation

The survey instrument was designed to align with the study's theoretical framework and analytic model, including Likert-scale items and open-ended questions capturing the following constructs:

1. Perceived Network Quality – speed, reliability, latency, stability during peak usage, and coverage.
2. Technology Acceptance (TAM) – perceived usefulness and ease of use of digital learning platforms.
3. Facilitating Conditions (UTAUT) – perceptions of whether campus infrastructure supports effective digital learning.
4. Student Engagement – behavioral engagement (attendance, participation, task completion) and cognitive engagement (focus, effort, deeper thinking).
5. Perceived Learning Experience – self-reported learning quality, efficiency, and confidence in hybrid and digital courses.

Items were adapted from validated instruments. Open-ended questions captured benefits and challenges.

Preliminary Findings

Survey responses (n = 82) came from 31 freshmen, 24 sophomores, 10 juniors, 12 graduate students, and 5 staff members, with nearly 89% reporting daily or frequent use of Wi-Fi in the student center and most using multiple devices for academic work. Awareness of the specific Wi-Fi 6E upgrade was low: only 12% knew about it, 35% believed their devices were compatible,

and 62% were unsure, indicating that perceptions were largely based on experience rather than technical knowledge.

Respondents reported strongly positive perceptions of network speed, reliability, and stability, including during peak usage. These perceptions were associated with greater ease of use and usefulness of digital learning platforms, consistent with TAM and UTAUT. Facilitating conditions were viewed positively within the upgraded space but less consistently across campus.

Behavioral engagement showed the clearest gains, with students reporting reliable attendance, timely task completion, and improved efficiency. Cognitive engagement and deeper learning showed more modest changes, with many students reporting neutral or small improvements in focus and higher-order thinking. This pattern suggests that improved connectivity mainly reduces technical barriers to participation rather than directly driving deep learning. Remaining concerns included uneven coverage, device compatibility, and unclear support processes, highlighting the need for consistent infrastructure and responsive institutional support, especially in the HBCU context where campus Wi-Fi often serves as a primary academic resource.

Planned Analyses and Data Integration

The final study will triangulate survey findings with additional objective data sources:

1. Network Telemetry (Pre/Post Deployment) – throughput, latency, jitter, and client distribution, aggregated by academic schedules to capture peak usage.
2. Learning Management System (LMS) Data – login frequency, session duration, submission timing, and participation in synchronous activities to support self-reported engagement.
3. Quasi-Experimental Analysis – a difference-in-differences (DiD) approach comparing changes in the upgraded student center and a matched comparison building, controlling for course and time fixed effects.
4. Mediation Pathways – testing whether engagement mediates the relationship between network performance and perceived learning experiences, as suggested by the conceptual framework.

Ethical Considerations

All survey data were collected anonymously. Planned telemetry and LMS data will be aggregated, de-identified, and accessed in accordance with institutional approvals. No instructional interventions were implemented, minimizing participant risk.

Limitations

This work-in-progress relies on self-reported perceptions from a single post-deployment survey in one campus space, limiting generalizability. The absence of pre-deployment survey data and

objective measures of network performance or LMS engagement precludes causal inference and limits the ability to triangulate perceived improvements with actual behavioral changes. The sample size also constrains statistical power and subgroup analyses, reflecting the current stage of the study.

Conclusion

This work-in-progress positions campus wireless infrastructure as an enabling condition for hybrid and digital learning. Preliminary evidence shows that Wi-Fi 6E improved perceived network quality and supported behavioral engagement, while deeper cognitive gains were more limited.

Future analyses will determine whether infrastructure improvements translate into measurable engagement and learning changes. For engineering educators and administrators, the study emphasizes that network upgrades must be paired with pedagogical and institutional support to meaningfully enhance student learning especially in equity-relevant contexts such as HBCUs.

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