

Awareness, Use, and Perceived Educational Value of Arduino-Based Interactive Learning for Digital Pedagogy in STEM Education in Southeast Nigeria

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Abstract

The increasing use of technology-mediated instruction has created interest in low-cost, interactive tools that can connect abstract STEM concepts with practical activities. Arduino-based learning is particularly relevant to digital electronics because it can support experimentation with circuits, programming, and logic operations. This study examined students' awareness and reported use of Arduino-based interactive learning, educators' perceptions of its educational value, and barriers to adoption in selected federal universities in Southeast Nigeria. A descriptive survey design was used because the study sought to describe existing awareness, reported practices, perceptions, and institutional conditions without manipulating an instructional intervention. The study involved 75 respondents comprising 25 lecturers and 50 final-year students from five federal universities. Data were collected in March 2025 using a structured questionnaire administered through Google Forms. The questionnaire contained demographic items and substantive clusters addressing awareness/use, perceived effectiveness, and barriers to adoption. Responses were analysed using means and standard deviations, with decision intervals of 1.00–1.74 = very low, 1.75–2.49 = low, 2.50–3.24 = moderate, and 3.25–4.00 = high. The reported overall internal-consistency reliability was Cronbach's $\alpha = 0.87$. Students showed moderate awareness of Arduino as a concept but low levels of reported practical use and confidence. Educators perceived Arduino-based activities as useful for classroom engagement and understanding of logic-gate concepts, while cost, limited training, and weak institutional support were identified as adoption barriers. The findings indicate a gap between general awareness and practical integration and support the need for targeted capacity development, appropriate laboratory provision, and institutional mechanisms for sustained technology integration.

Keywords: Arduino; Digital pedagogy; STEM education; Digital electronics; Interactive learning; Higher education; Nigeria

1. Introduction

Digital competence is increasingly treated as a component of effective participation in contemporary learning and work environments. Ferrari (2012), for example, conceptualised digital competence as a combination of knowledge, skills, and attitudes required for confident, critical, and creative use of digital technologies. In higher education, this places pressure on teaching approaches to move beyond the passive consumption of technological content toward learning experiences in which students can apply, test, troubleshoot, and create. Curriculum research likewise

argues that digital skills should be embedded across learning rather than treated only as specialist knowledge (Parsons et al., 2020).

Within STEM education, the theory–practice relationship is especially important because students are expected to connect conceptual representations with observable systems and procedures. Evidence from integrated STEM research indicates that appropriately designed STEM learning can support problem solving, scientific creativity, and critical-thinking dispositions (Hebebe & Usta, 2022). These findings provide a broader pedagogical basis for investigating interactive tools such as the Arduino tool to

enable learners work with concrete representations of abstract concepts.

Arduino is an open-source microcontroller platform that can be used to construct, program, and test electronic systems. In digital electronics, interactive activities can allow learners to represent logic operations, observe outputs, modify code, and troubleshoot circuit behaviour. The educational value of such activities is consistent with experiential and constructivist views of learning, in which learners develop understanding through active engagement with tasks and reflection on the consequences of their actions. However, the educational value of a technology cannot be assumed merely from its technical capability; its usefulness depends on access, staff competence, curriculum integration, and institutional support.

According to Xiong (2021), with innovative teaching practices, students in the experimental classes will be able to fully understand and master the basic theory, methods, and practical skills will be greatly enhanced. At the same time, the Nigerian higher-education context presents infrastructure, training, and resource constraints that can affect whether an instructional technology is actually used. Although Arduino-related research has expanded rapidly, most studies focus on primary and secondary education, leaving higher education comparatively under-explored. Arduino as a physical computing platform enables students to work with real hardware under authentic failure conditions, supports iterative hardware–software prototyping that reflects professional engineering practice, and provides an accessible end-to-end experimental system, from sensor-based data acquisition to embedded control (Polatuly et al., 2026)

Interactive STEM pedagogies and digital technologies each contribute distinct, evidence-based mechanisms for enhancing student engagement and practical skill acquisition. A meta-analysis of 225 STEM studies found that active learning increased exam performance by nearly half a standard deviation and reduced course failure rates by 55% (Del Mundo, 2025). But in the context of this study, is to address the relationship between students' awareness and reported practical use of Arduino-based learning, educators' perceptions of its educational value, and the institutional barriers that may constrain adoption across five federal universities in Southeast Nigeria. The problem is therefore not simply the availability of Arduino technology; rather, it concerns whether learners and educators possess sufficient awareness and practical familiarity, whether educators perceive the technology as educationally useful, and whether institutional conditions support sustained use. Addressing these questions is important because the transition from theoretical knowledge to practical competence is a central concern in digital-electronics education.

Purpose of the Study

The purpose of the study was to examine awareness and reported use of Arduino-based interactive learning for digital pedagogy, educators' perceptions of its educational value, and barriers to adoption in selected federal universities in Southeast Nigeria.

Research Questions

1. What is the level of students' awareness and reported use of Arduino-based interactive learning for digital electronics in the selected universities?
2. How do educators perceive the effectiveness of Arduino-based interactive

learning for teaching and learning digital-design concepts?

3. What barriers do educators identify as constraining the adoption of Arduino-based interactive learning in the selected universities?

Theoretical Orientation

The study is informed by constructivist and experiential perspectives on learning. From a constructivist perspective, learners develop understanding through active interaction with tasks and prior knowledge. From an experiential perspective, learning is strengthened when learners engage in concrete activity, examine outcomes, and use those outcomes to refine subsequent action. Arduino-based practical activities are consistent with these perspectives because they can make abstract logic operations observable through circuit construction, programming, testing, and troubleshooting. The present descriptive study does not test these theories experimentally; they provide a pedagogical lens for interpreting why respondents may perceive interactive activities as useful.

2. Methodology

Research Design

A descriptive survey design was adopted. The design was appropriate because the study sought to obtain a cross-sectional description of existing awareness, reported use, perceived educational value, and barriers to adoption among lecturers and students. No instructional treatment was assigned, and no experimental comparison was made; consequently, a descriptive design allows the study to report the distribution and intensity of respondents' perceptions without making causal claims about learning outcomes. Creswell and Creswell (2018) identify survey approaches as suitable for collecting quantitative

information about characteristics, attitudes, and perceptions within a population.

Population and Sample

The study focused on lecturers and final-year students in relevant programmes within five federal universities in Southeast Nigeria: University of Nigeria, Nsukka (UNN); Nnamdi Azikiwe University, Awka (UNIZIK); Alvan Ikoku Federal University of Education, Owerri (AIFUE); Michael Okpara University of Agriculture, Umudike (MOUAU); and Alex Ekwueme Federal University, Ndufu-Alike (FUNAI). The choice of these institutions was intended to provide coverage across federal higher-education settings in the South-East where digital-electronics teaching and STEM-related programmes are offered. The study sample comprised 75 respondents: 25 lecturers and 50 students.

Purposive sampling was used to identify lecturers with relevant experience in digital electronics or technology-supported instruction, while balloting was reported as the procedure used to select final-year students. The combined use of purposive selection for the lecturer cohort and balloting for the student cohort should be reported explicitly because the two cohorts had different selection procedures.

University	Lecturer (n = 25)	Students (n = 50)	Total (n = 75)
UNN	7	10	15
UNIZIK	5	10	15
AIFUE	5	10	15
MOUAU	4	10	15
FUNAI	4	10	15
TOTAL	25	50	75

Instrument for Data Collection

Data were collected with a structured questionnaire administered electronically through Google Forms. Based on the items reported in the supplied manuscript, the

questionnaire comprised four sections/clusters. Section A collected demographic information. Section B addressed students' awareness and reported practical use of Arduino-based interactive learning and contained seven substantive items (Items 1–7). Section C addressed educators' perceived effectiveness of Arduino-based simulation for teaching and learning digital-design concepts and contained three substantive items (Items 8–10). Section D addressed barriers to adoption and contained four items (Items 11–14). The substantive items were rated on a four-point response scale. The decision intervals were: 1.00–1.74 = very low; 1.75–2.49 = low; 2.50–3.24 = moderate; 3.25–4 and the overall Cronbach's alpha for the instrument was 0.87, indicating good internal consistency for the instrument as a whole.

Validation.

The instrument was administered via Google Forms to 3 experts in the departments of computer and robotics education and 2 experts in the department of computer engineering, all from the University of Nigeria, Nsukka, for face and content validation. Corrections were made after the instrument was collected.

Section B

Research Question 1: What is the level of students' awareness and reported use of Arduino-based interactive learning for digital electronics?

SN	Item Statements	$\bar{x}$	SD	Remark
1	I have heard of Arduino and understand its purpose	2.78	0.91	Moderate
2	I am aware that Arduino can be used for logic-gate simulation	1.76	0.84	Low
3	I have personally simulated logic gates with Arduino	1.94	0.82	Low
4	My department offers structured Arduino laboratory sessions	1.88	0.79	Low

Data Collection Procedure

Data were collected in July 2025 using Google Forms. The electronic format facilitated distribution to respondents across the participating universities and enabled the responses to be compiled for statistical analysis. The researcher sought the consent of the participants before administering the instrument and promised to protect confidentiality.

Data Analysis and Decision Rules

Responses collected were analysed using International Business Machines (IBM) Statistical Product and Service Solutions (SPSS) version 27. Descriptive statistics means and standard deviations were used to answer the research questions. For interpretation, mean scores of 1.00–1.74 were classified as very low, 1.75–2.49 as low, 2.50–3.24 as moderate, and 3.25–4.00 as high. The same decision rule was applied consistently to the substantive Likert-type items.

3. Results

The results are presented in accordance with the three research questions. Research Question 1 addresses students' awareness and reported use; Research Question 2 addresses educators' perceived effectiveness; and Research Question 3 addresses barriers to adoption.

5	I can independently wire basic circuits on Arduino	2.05	0.85	Low
6	I can write and modify Arduino sketches for logic gates	1.99	0.83	Low
7	I feel confident using Arduino for simulations	2.18	0.90	Low

The results in Table 1 indicate that students had some general familiarity with Arduino, but this awareness did not extend consistently to practical application. The highest-rated item concerned general awareness of Arduino, whereas awareness of

Section C

Research Question 2: How do educators perceive the effectiveness of Arduino-based interactive learning for teaching and learning digital-design concepts?

SN	Item Statements	$\bar{x}$	SD	Remark
8	Arduino systems improve classroom engagement	3.40	0.50	High
9	Arduino enhances student understanding of logic gates	3.30	0.60	High
10	Students grasp complex circuits better with Arduino	3.20	0.70	Moderate

Table 2 showed how educators generally perceived Arduino-based activities as beneficial for engagement and understanding of digital-design concepts. The strongest pattern concerned classroom engagement, followed by understanding of

Section D

Research Question 3: What barriers do educators identify as constraining the adoption of Arduino-based interactive learning?

SN	Item Statements	$\bar{x}$	SD	Remark
11	Cost is a major constraint	3.30	0.70	High
12	Lack of training hinders adoption	3.20	0.60	Moderate
13	Institutions provide adequate support	2.10	0.90	Low
14	More training would enhance integration	3.40	0.60	High

The result in Table 3 indicates that cost and the perceived need for additional training were prominent constraints, while institutional support was rated low. The results therefore point to both resource and

its use for logic-gate simulation and reported practical activities remained low. The pattern suggests a distinction between knowing about the technology and possessing the opportunity or confidence to use it.

logic gates; perceptions concerning complex circuits were moderate rather than high. This distinction is important because it indicates that respondents did not rate every dimension of perceived effectiveness identically.

organisational dimensions of adoption rather than a purely technical problem.

4. Discussion of Results

The first research question shows a clear distinction between general awareness and practical familiarity. Students appear to recognise Arduino as a technology, yet their reported exposure to logic-gate simulation, structured laboratory sessions, circuit wiring, programming, and independent use remains limited. A plausible explanation is that awareness can develop through general exposure to digital technology without corresponding access to structured practical activities. In a university setting, practical use also depends on equipment availability, laboratory scheduling, instructor competence, curriculum emphasis, and opportunities for repeated practice. The finding is therefore better interpreted as an awareness–practice gap than as a lack of interest in technology.

This interpretation is consistent with the broader literature cited in the manuscript, which emphasises the importance of embedding digital skills in meaningful curricular activity rather than treating technology as an isolated competency. Parsons et al. (2020) argue for curricula that integrate digital skills across learning, while the STEM literature indicates that active and integrated learning can support higher-order competencies. The present findings extend that discussion by showing that access to a potentially useful platform does not automatically translate into practical competence.

The second research question indicates that educators generally perceive Arduino-based activities as educationally useful, particularly for engagement and the understanding of logic-gate concepts. A plausible pedagogical explanation is that interactive circuit activities provide immediate feedback: students can manipulate a system, observe outputs, identify errors, and revise their designs.

Such activity is compatible with experiential learning because the learner moves between concrete activity, observation, interpretation, and further action. It is also compatible with constructivist learning because conceptual understanding can be developed through active interaction with representations of the target concept.

The third research question indicates that adoption is shaped by contextual conditions. Cost was identified as an important constraint, and respondents also indicated a need for further training. Low perceived institutional support suggests that sustainable adoption may require more than individual lecturer enthusiasm. Possible institutional mechanisms include provision of laboratory equipment, maintenance and replacement arrangements, staff development, curriculum integration, technical support, and clear departmental policies. These interpretations are consistent with the broader digital-education literature, which repeatedly identifies infrastructure, skills, and institutional capacity as interconnected conditions for meaningful technology integration.

Importantly, the results do not demonstrate that Arduino instruction causes improved student engagement or conceptual understanding because the study did not employ an experimental or quasi-experimental design and did not directly measure learning gains. The appropriate conclusion is that respondents reported perceptions and experiences that are compatible with the potential pedagogical value of Arduino-based learning. Future intervention studies could test whether structured Arduino activities produce measurable changes in students' conceptual understanding, practical competence, problem-solving ability, or engagement.

5. Conclusion

The study examined awareness and reported use of Arduino-based interactive learning, educators' perceived educational value, and barriers to adoption in selected federal universities in Southeast Nigeria. The results reveal a consistent gap between general student awareness and practical familiarity. Educators, in contrast, reported generally favourable perceptions of the educational usefulness of Arduino-based activities, particularly for engagement and understanding of logic-gate concepts. At the same time, cost, training needs, and limited institutional support emerged as important constraints. Taken together, the findings suggest that the educational potential of Arduino-based learning depends on the availability of practical opportunities, staff capacity, and institutional support rather than on awareness of the technology alone.

6. Recommendations

1. Universities should consider structured practical sessions in which students repeatedly design, wire, program, test, and troubleshoot Arduino-based digital circuits.
2. Departments should strengthen professional development opportunities for lecturers who teach digital electronics and related STEM courses.
3. Institutions should develop realistic procurement, maintenance, and replacement plans for low-cost microcontroller and laboratory equipment.
4. Curriculum planners should specify where Arduino-based activities can support existing digital-electronics learning outcomes rather than treating the technology as an optional add-on.
5. Future studies should use experimental or quasi-experimental

designs to test changes in conceptual understanding, practical competence, problem solving, and engagement attributable to structured Arduino-based instruction.

7. Limitations

The study used a descriptive survey and therefore did not establish causal effects of Arduino-based learning on student outcomes. The sample was limited to 75 respondents across five federal universities, and the use of purposive sampling for lecturers limits statistical generalisation beyond respondents with comparable characteristics. In addition, the study did not provide the university-level sample allocation or the full psychometric validation record. Finally, perceptions of educational value are not equivalent to objectively measured learning gains; future research should incorporate achievement tests, performance tasks, classroom observations, or experimental comparisons.

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