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Perceived Usefulness of Logic Circuit Design in Enhancing Technical Proficiency Among BSIT Students in Nueva Ecija University of Science and Technology- Peñaranda Off-Campus

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Abstract:

This research evaluates the perceived usefulness and technical proficiency of eighty-four (84) Bachelor of Science in Information Technology (BSIT) students at the Peñaranda Off-Campus (POC) site following the implementation of logic circuits for 7-segment displays. Utilizing a Quantitative Method with a correlational-descriptive design, the study analyzes the transition from theoretical logic design to physical hardware prototyping. The participants used a structured workflow that included truth table construction, Karnaugh Map (K-map) reduction, and the application of 74XX-series logic ICs with 21 LEDs. Empirical results yielded an overall weighted mean of 3.43 ("Effective") for logic design concepts and 3.49 ("Proficient") for technical proficiency. Statistical analysis at an alpha level of 0.05 confirmed no significant relationship between the respondents' demographic profiles and their technical assessments, validating the methodology as an equitable and gender-neutral pedagogical model. The study identifies a "Fixing vs. Foundation" gap, where high troubleshooting proficiency is contrasted by lower scores in mathematical optimization and wiring precision (3.32–3.37), suggesting the need for a simulation-first approach to bridge the gap between abstract theory and physical assembly.

Keywords — **Logic Circuits, BSIT, Equitable Technical Education, K-Map, Technical Proficiency, Gender Neutrality, POC.**

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I. INTRODUCTION

The evolution of digital systems has made the understanding of logic circuit design a cornerstone of Information Technology education [1]. Mastery of Boolean logic and hardware implementation is essential for students to comprehend how data is processed at the machine level [2]. At the Nueva Ecija University of Science and Technology (NEUST), the College of Information and Communications Technology (CICT) emphasizes hands-on laboratory experiences to bridge the gap between theoretical Discrete Mathematics and practical hardware application.

A critical component of this technical training is the design and implementation of logic circuits for 7-segment displays. These displays, which utilize segments labelled 'a' through 'g', require students to map binary inputs to specific visual outputs representing digits 0 through 9. The design process involves a rigorous sequence: constructing truth tables to define segment activation, utilizing Karnaugh Maps (K-maps) for Boolean simplification, and applying "Don't Care" (X) conditions to optimize the circuit for invalid binary inputs.

This study evaluates explicitly the experiences of eighty-four (84) BSIT students during the Peñaranda Off-Campus (POC) study. These students used 74XX-series logic ICs, 21 LEDs, and breadboards to turn their theoretical diagrams into functional hardware. By analysing the perceived usefulness of this "design-to-construction" cycle in the POC setting, this research seeks to quantify how such off-campus technical activities enhance the technical proficiency and career readiness of Information Technology students.

Statement of the Problem

1. What is the demographic profile of the respondents in POC in terms of Sex and Role in the Group?
2. How do the respondents perceive the usefulness of Logic Design Concepts, specifically truth table construction, K-map simplification, the use of "Don't Care" conditions, and segment activation analysis?
3. What is the level of Technical Proficiency enhanced among students regarding the use of 74XX series ICs, wiring 21 LEDs, power management, and troubleshooting?
4. How do students perceive the Professional and Career Relevance of logic gate integration and technical documentation?
5. Is there a significant relationship between respondents' demographic profiles and their assessments of design concepts, technical proficiency, and career relevance?
6. What curriculum improvements for hardware laboratory activities can be proposed based on the findings from the POC study?

Hypotheses

Based on the objectives of this study at the Peñaranda Off-Campus (POC), the following null hypotheses are tested at a 0.05 level of significance:

$H_0 1$: There is no significant correlation between the Sex of the respondents and their perceived usefulness of Logic Design Concepts.

$H_0 2$: There is no significant correlation between the Sex of the respondents and their enhanced Technical Proficiency.

$H_0 3$: There is no significant correlation between the Sex of the respondents and their perceived Professional and Career Relevance of the project.

$H_0 4$: There is no significant correlation between the Role in Group (Leader or Member) and the perceived usefulness of Logic Design Concepts.

$H_0 5$: There is no significant correlation between the Role in Group and the level of enhanced Technical Proficiency.

$H_0 6$: There is no significant correlation between the Role in the Group and the perceived Professional and Career Relevance of the logic circuit implementation.

II. METHODOLOGY

This section describes the systematic approach used to evaluate students' perceived usefulness and technical proficiency during the logic circuit implementation phase. The research ensures that the findings accurately represent the experiences of the eighty-four (84) respondents during the Peñaranda Off-Campus (POC) study.

A. Research Design

The study utilized a Quantitative Method to collect and analyze numerical data regarding student perceptions and performance. Specifically, a Correlational Descriptive Design was employed to assess existing conditions and identify relationships among variables. This design allowed the researchers to describe the current state of students' technical proficiency while simultaneously identifying if significant relationships exist between their demographic profiles (Sex and Role) and the research variables. This approach aligns with standard educational research methodologies that seek to evaluate the effectiveness of curriculum-based case studies [3].

B. Respondents and Sampling Technique

The respondents of the study consisted of eighty-four (84) Bachelor of Science in Information Technology (BSIT) students from Nueva Ecija University of Science and Technology. These participants were previously enrolled in Discrete Mathematics and participated in the Peñaranda Off-Campus (POC) activity. The research used Total Enumeration as the sampling technique, meaning the

entire student population within the specified cohort was included to ensure high data reliability and complete representation, a method often cited as superior for small, defined populations in technical studies [4].

C. Research Instrument

A structured survey questionnaire, validated for clarity and alignment with the case study objectives, served as the primary data collection tool. The instrument was divided into three main parts:

1. Logic Design Concepts: Measuring the utility of truth tables, K-maps, and Boolean simplification.
2. Technical Proficiency: Evaluating hands-on skills in wiring 21 LEDs, using 74XX series ICs, and troubleshooting.
3. Career Relevance: Assessing the perceived value of the project for future professional IT roles.

The survey used a 5-point Likert scale to quantify students' agreement with specific indicators [5].

D. Data Collection Procedure

The data collection followed the completion of a structured 5-step case study[10].

Step 1: Students identified segments 'a' through 'g' and determined activation patterns for digits 0-9.

Step 2: Participants constructed truth tables and utilized "Don't Care" (X) conditions for invalid binary inputs.

Step 3: Students created 4-variable K-maps to derive simplified Boolean expressions for each segment.

Step 4: Logic circuit diagrams were designed using gates such as AND, OR, and NOT.

Step 5: Students built the physical circuit on a breadboard using 74XX logic ICs and 21 LEDs, followed by rigorous troubleshooting.

E. Statistical Treatment of Data

The following statistical tools were used to analyze the collected data:

- Weighted Mean (WM): Used to determine the average response for each indicator and provide a verbal interpretation based on the statistical interpretation scale.
- Frequency and Percentage: Used to describe the demographic profile of the respondents (Sex and Role).
- Pearson Correlation Coefficient (r): Employed to test the null hypotheses (H_0) and determine the relationship between student profiles and their perceived proficiency [6].

III. RESULTS

This section presents the findings derived from the quantitative data collected from eighty-four (84) BSIT students at Nueva Ecija University of Science and Technology during the Peñaranda Off-Campus (POC) study. The results are categorized by respondents' demographic profile and by weighted mean scores across the three research domains.

A. Demographic Profile of the Respondents

The researchers employed total enumeration to include all participants from the specified cohort. The demographic profile focuses on two key attributes: Sex and Role in the Group.

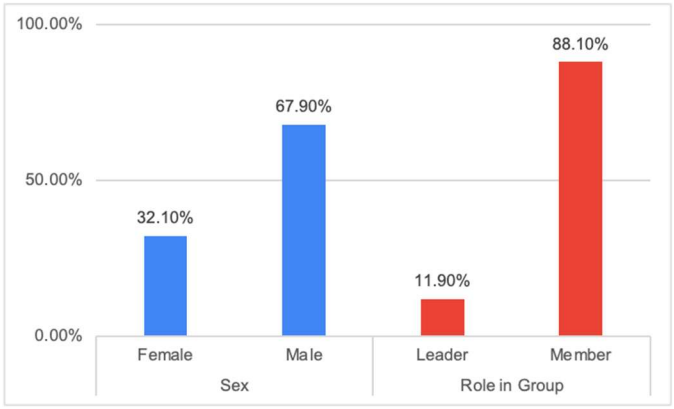

Figure 1. Demographic Distribution of the Respondents

As shown in Figure 1, the participant population is predominantly male, accounting for 67.90% of the total, while females represent 32.10%. Regarding project leadership, 11.90% of the respondents identified as Group Leaders, whereas the majority, 88.10%, served as Group Members. This distribution reflects the group dynamics during the implementation of the 7-segment display logic circuits.

B. Perceived Usefulness of Logic Design Concepts

This domain assesses students' understanding of the theoretical and analytical phases of the case study. The results indicate that respondents found the structured design process to be effective for their learning.

TABLE I
PERCEIVED USEFULNESS OF LOGIC DESIGN CONCEPTS

Indicators	Mean	Verbal Description	Verbal Interpretation
1. Constructing truth tables for digits 0-9 provided a clear framework for mapping binary inputs to segment outputs.	3.48	Agree	Effective
2. Using K-maps was an effective tool for simplifying Boolean expressions for segments 'a' through 'g'.	3.37	Neutral	Moderately Effective
3. Applying "Don't Care" conditions (X) helped me understand how to simplify circuits for invalid binary inputs (10-15).	3.46	Agree	Effective
4. Deriving Boolean expressions from K-maps increased my ability to translate logic into functional diagrams.	3.32	Neutral	Moderately Effective
5. The process of segment activation analysis improved my logical reasoning.	3.54	Agree	Effective
Overall Weighted Mean	**3.43**	**Agree**	**Effective**

As shown in Table I, the overall weighted mean of 3.43 suggests that the students perceive the logic design phase as an effective component of their technical training. While K-map simplification (3.37) and deriving expressions (3.32) showed moderate effectiveness—indicating a steeper learning curve for these mathematical tasks—the high score for segment activation analysis (3.54) proves that students successfully mastered the logic required to represent numbers 0-9.

C. Enhancement of Technical Proficiency

This section measures the development of hands-on skills during the physical assembly and testing of the 7-segment display on a breadboard.

TABLE II
ENHANCEMENT OF TECHNICAL PROFICIENCY

Indicators	Mean	Verbal Description	Verbal Interpretation
1. Using 74XX Series Logic ICs enhanced my knowledge of hardware components.	3.44	Agree	Proficient
2. The physical wiring of 21 LEDs on a breadboard improved my precision in hardware assembly.	3.36	Neutral	Moderately Proficient
3. Implementing the 9V battery and voltage regulator taught me essential skills in power management.	3.46	Agree	Proficient
4. Setting up four push buttons for binary inputs (A, B, C, D) helped me understand digital input-output interfaces.	3.5	Agree	Proficient
5. The testing and troubleshooting phase improved my problem-solving skills.	3.7	Agree	Proficient
Overall Weighted Mean	**3.49**	**Agree**	**Proficient**

The data in Table II reveal that the highest individual mean in the entire study was recorded for the testing and troubleshooting phase (3.70). This indicates that the POC activity was highly successful in developing students' diagnostic and problem-solving abilities. The moderate proficiency in wiring 21 LEDs (3.36) reflects the physical complexity of the task, which required connecting 3 LEDs per segment for a total of 7 segments.

D. Professional and Career Relevance

This domain assesses the long-term value students place on these hardware competencies for their future as IT professionals.

TABLE III
PROFESSIONAL AND CAREER RELEVANCE

Indicators	Mean	Verbal Description	Verbal Interpretation
1. Mastery of logic gate integration is a fundamental skill for my future IT career.	3.33	Neutral	Moderately Relevant
2. The design-to-construction cycle increased my confidence in handling complex technical projects.	3.3	Neutral	Moderately Relevant
3. The ability to document circuit results is a professional skill I can use in the industry.	3.48	Agree	Relevant
4. Understanding 7-segment display logic provides a foundation for learning advanced digital systems.	3.45	Agree	Relevant
5. I find this hands-on implementation more useful than theoretical learning alone.	3.5	Agree	Relevant
Overall Weighted Mean	**3.41**	**Agree**	**Relevant**

In Table III, the respondents expressed that hands-on implementation is more useful than purely theoretical learning (3.50). While some students remained neutral regarding how these specific gates apply to their future roles, they recognized that the logic provides a necessary foundation for advanced systems (3.45).

E. Correlation Analysis of Demographic Profile and Research Variables

This section evaluates the potential relationship between the demographic profiles (Sex and Role) of the eighty-four (84) respondents and their respective assessments of the logic circuit implementation. The statistical analysis was performed using a significance level (α) of 0.05.

TABLE IV
CORRELATION MATRIX: DEMOGRAPHIC PROFILE VS. RESEARCH VARIABLES

Profile Variable	Statistical Value	Usefulness of Design Concepts	Technical Proficiency	Career Relevance
Sex	r	0.043	-0.055	0.013
	p	0.699	0.618	0.905
Role in Group	r	-0.151	-0.139	-0.083
	p	0.17	0.209	0.453

The correlation results summarized in Table IV demonstrate a high degree of gender neutrality in the technical assessment of the respondents. Specifically, the p-values for the variable of Sex in relation to Perceived Usefulness (0.699), Technical Proficiency (0.618), and Career Relevance (0.905) are all significantly higher than the established 0.05 alpha level. This outcome demonstrates that the perceived utility of logic design and the acquisition of technical skills—including the complex wiring of 21 LEDs and the integration of 74XX-series logic ICs—remained consistent across respondents' genders. Similarly, the p-values for the respondent's Role in Group regarding Usefulness (0.170), Proficiency (0.209), and Relevance (0.453) exceed the threshold for statistical significance. Such findings suggest that the practical experiences of troubleshooting physical circuits and simplifying Karnaugh Maps provided equal learning value to both group leaders and members. Furthermore, the Pearson r values, which range from -0.151 to 0.043, indicate a very weak to negligible correlation between these demographic factors and the research variables. Based on this statistical evidence, the researchers fail to reject the Null Hypotheses (H_0). The results confirm that the demographic profiles of the BSIT students participating in the Peñaranda Off-Campus (POC) study did not significantly influence their proficiency levels or their overall perceptions of the project's relevance. Ultimately, this implies that the case study's hands-on methodology, which involves translating binary inputs for the digits 0-9 into segment-activation patterns, serves as an equitable and effective pedagogical tool for all students. This consistency across gender and group responsibility underscores the robustness of the hardware-based curriculum in fostering technical competency within the Information Technology program at the Nueva Ecija University of Science and Technology.

IV. DISCUSSION

The results of the Peñaranda Off-Campus (POC) study highlight a critical "Fixing vs. Foundation" gap in the technical development of BSIT students. While the cohort demonstrated a high level of troubleshooting proficiency (3.70), there was a measurable decrease in performance during the foundational mathematical phases, such as K-map simplification (3.37) and Boolean expression derivation (3.32).

A. The "Fixing vs. Foundation" Gap

This discrepancy suggests that students possess strong resilience and resourcefulness when diagnosing physical circuit errors but struggle with the abstract mathematical optimization required before assembly. The lower **wiring precision score (3.36)** further indicates that without a solid mathematical "blueprint," the physical transition to a breadboard with **21 LEDs** becomes a trial-and-error process rather than a calculated implementation. This finding aligns with the observation that students may perceive the theoretical design as a hurdle rather than a tool for simplifying hardware complexity.

B. Equitable and Gender-Neutral Learning

A significant finding of this research is the confirmation of **gender neutrality** in technical outcomes. Statistical analysis showed no significant relationship between sex and technical proficiency ($p = 0.618$) or career relevance ($p = 0.905$). This proves that the project-based methodology utilized at the POC site is an **equitable pedagogical model**, ensuring that both male and female students achieve comparable levels of technical competency regardless of the initial gender distribution.

C. Bridging the Gap via Simulation

To address the "Fixing vs. Foundation" gap, the study suggests that a **simulation-first approach** is necessary. By using digital tools to validate K-map results before physical breadboarding, students can visualize the logic flow, which serves as a cognitive bridge to improve wiring precision and deepen their foundational understanding. This structured workflow ensures that students' troubleshooting skills are built on a mathematically sound design.

V. CONCLUSION

Based on the findings of the study conducted at the Nueva Ecija University - Peñaranda Off-Campus (POC) study, the following conclusions are drawn according to the specific research objectives:

1. Demographic Profile. The student population involved in the logic circuit implementation is predominantly male, with a minority representation of females. Furthermore, the project structure relies heavily on a distributed group dynamic, in which the vast majority of students serve as group members under a small number of designated leaders.
2. Usefulness of Logic Design Concepts. Students perceive the theoretical design phase as an overall effective component of their technical training. While the analytical tasks of simplifying Karnaugh Maps and deriving Boolean expressions are viewed as moderately effective—suggesting a higher level of cognitive difficulty—the practical utility of truth tables and segment activation analysis provides a solid logical foundation for mapping binary inputs to the 7-segment display for digits 0-9.
3. Level of Technical Proficiency. The hands-on application significantly enhances students' technical proficiency, particularly in testing and troubleshooting. Students demonstrate high competency in using 74XX-series logic ICs and managing power requirements with 9V batteries and regulators. Although wiring 21 LEDs remains a challenging task, the activity successfully develops the problem-solving skills necessary to align physical outputs with theoretical truth tables.
4. Professional and Career Relevance. Respondents recognize the high professional value of hands-on implementation over purely theoretical learning. The ability to document complex circuit results and understand the underlying logic of 7-segment displays is perceived as a relevant foundation for advanced digital systems and future careers in the Information Technology industry.
5. Correlation of Profile and Results. Statistical analysis indicates no significant relationship between respondents' demographic profiles (Sex and Role) and their assessments of logic design, technical proficiency, or career relevance. This indicates that the case study methodology used in the POC study is an equitable pedagogical tool that delivers consistent learning outcomes to all BSIT students regardless of gender or group responsibility.
6. Curriculum Improvements. Based on the lower mean scores in specific areas, there is a clear need to provide more focused laboratory hours for K-map simplification and breadboard wiring precision. Strengthening these areas will ensure that the transition from abstract logic to physical hardware implementation is more seamless for future IT cohorts.

VI. RECOMMENDATIONS

Based on the findings and conclusions of the study conducted during the Nueva Ecija University of Science and Technology - Peñaranda Off-Campus (POC) activity, the following recommendations are proposed to enhance the learning experience and

technical outcomes for BSIT students at Nueva Ecija University of Science and Technology:

1. Students should be required to validate their optimized logic using digital simulation tools prior to physical assembly to bridge the gap between theory and hardware.
2. The curriculum should incorporate advanced diagnostic techniques that require students to identify and repair intentional phantom faults, further refining their problem-solving resilience.
3. This project-based model should be institutionalized as a standard teaching tool, given its proven effectiveness as an equitable, gender-neutral pedagogical methodology.
4. The use of modular or pre-cut jumper wire kits is recommended to reduce physical complexity and allow students to focus primarily on logic flow.
5. A dedicated safety seminar focusing on circuit polarity and component thermal management should be integrated into the initial laboratory orientation phase.
6. The professor should establish a peer-led technical review system in which students validate each other's schematic designs before physical construction begins.
7. The institution should expand its hardware resources to ensure that every student has access to an individual kit for independent design and implementation.

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