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Evaluating Technical Competency and Practical Utility in Logic Gate Integration: A Case Study of BSIT Students at the NEUST Main Campus

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Abstract— This research evaluates the technical competency and practical utility of one hundred twelve (112) Bachelor of Science in Information Technology (BSIT) students at the Nueva Ecija University of Science and Technology (NEUST) Main Campus following the implementation of a logic gate integration project. Utilizing a Quantitative Correlative Descriptive Design with Simple Random Sampling via the fishbowl selection technique, the study analyzed the transition from theoretical Boolean simplification to physical hardware prototyping. The participants executed a structured workflow that included constructing truth tables, reducing Karnaugh Maps (K-maps) using "Don't Care" conditions, and assembling 7-segment display circuits using 74XX-series logic ICs and 21 LEDs. Empirical results yielded an overall weighted mean of 3.64 ("Effective") for logic design concepts, 3.67 ("Proficient") for technical proficiency, and 3.73 ("Relevant") for career utility. Demographic analysis revealed a sample composed of 77.70% males and 22.30% females, with 13.40% serving as group leaders. Statistical analysis using Pearson's r showed no significant relationship between respondents' demographic profiles and their technical assessments ($p > 0.05$), indicating that the project-based methodology provides equitable and consistent learning outcomes across the cohort. The study concludes that hands-on hardware implementation is a critical driver of technical growth and recommends the continued integration of complex prototyping in the IT curriculum.

Keywords— Technical Competency, BSIT, Logic Gate Integration, 7-Segment Display, K-Map, Fishbowl Selection, NEUST Main Campus.

I. INTRODUCTION

In the contemporary landscape of Information Technology, the ability to design and implement digital logic circuits remains a foundational requirement for understanding the intricate relationship between software and hardware. The foundational principles of Boolean algebra and the configuration of logic gates are essential for students to understand how data is processed at the machine level, serving as the bedrock of computer architecture (Mano & Kime, 2015). This research aims to evaluate the perceived utility and technical competency of Bachelor of Science in Information Technology (BSIT) students at the Nueva Ecija University of Science and Technology (NEUST) Main Campus. Specifically, the study assesses how the practical application of 7-segment display logic gates enhances the students' problem-solving abilities and career readiness. Despite the theoretical coverage of digital logic in Discrete Mathematics, many students face significant challenges when transitioning from abstract concepts to physical hardware implementation. There is often a disconnect between deriving a Boolean expression and

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successfully troubleshooting a malfunctioning circuit, which can hinder the development of core technical competencies (Wickert & Lewis, 2011). The students engaged in a structured five-step methodology: (1) identification of activation patterns for segments 'a' through 'g'; (2) construction of truth tables for decimal digits 0-9; (3) simplification of logic through Karnaugh Maps (K-maps) utilizing "Don't Care" conditions; (4) schematic design of logic gate diagrams; and (5) the physical assembly of circuits on a breadboard using 74XX series logic ICs and 21 LEDs. Mastery of these technical skills is crucial, as active learning and hands-on laboratory experiences have been shown to significantly increase student engagement and knowledge retention in technical disciplines (Prince, 2004). This hardware-centric project is designed to foster a higher level of technical proficiency that is directly applicable to professional IT environments.

Existing scholarship emphasizes that digital logic gates form the essential basis for more complex digital systems, including microprocessors and memory units (Floyd, 2014). Furthermore, integrating these practical projects ensures that the IT curriculum remains aligned with the evolving standards and rigorous demands of the global technology industry (Association for Computing Machinery [ACM], 2017). This study provides a comprehensive look at the learning outcomes of the Main Campus cohort. It examines whether students' confidence and perceived mastery of digital electronics. This research targets a sample of one hundred twelve (112) BSIT students selected through a simple random sampling technique, specifically employing the fishbowl selection method to ensure unbiased representation. The study hypothesizes that the demographic profile of these students does not significantly influence their technical competency, suggesting that the logic circuit integration project is a universally effective pedagogical tool.

II. METHODOLOGY

The study utilized a Quantitative Correlational Descriptive Design. This approach is designed to describe students' current technical proficiency and to identify whether a significant relationship exists between their demographic profiles and their technical outcomes. The respondents of the study were 112 Bachelor of Science in Information Technology (BSIT) students at the NEUST Main Campus. To ensure an unbiased representation of the population, the researchers employed simple random Sampling via a fishbowl selection technique. In this process, the names of all eligible students with a background in Discrete Mathematics were placed in a container, and 112 names were drawn at random to constitute the final sample.

A structured survey questionnaire served as the primary data collection tool. The instrument was partitioned into three specific domains:

- Logic Design Concepts. Evaluating the utility of truth tables, K-mapping, and Boolean simplification.
- Technical Proficiency. Measuring hands-on skills in circuit assembly, IC utilization, and troubleshooting.
- Career Relevance. Assessing the long-term professional value of hardware-related competencies.
- The survey utilized a 5-point Likert scale, where respondents indicated their degree of agreement with various performance indicators.

The researchers followed a rigorous laboratory workflow to ensure data reliability. First, students identified the activation patterns for segments 'a' through 'g' for a 7-segment display. Second, students constructed truth tables

MIJRD Multidisciplinary International Journal of Research and Development

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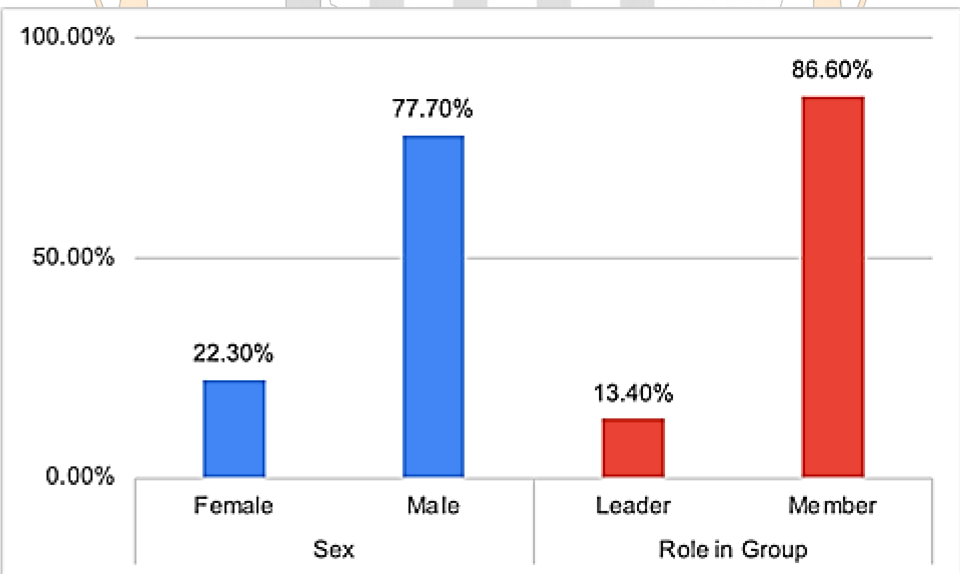
and simplified logic using Karnaugh Maps (K-maps). Third, the simplified logic was translated into a physical circuit on a breadboard using 74XX series logic ICs and 21 LEDs. Upon completion of the physical implementation and troubleshooting phase, the survey was administered to the 112 randomly selected participants. To address the research questions systematically, the following statistical methods were employed:

- **Frequency and Percentage Distribution.** Used to summarize the demographic profile of the respondents in terms of Sex and Role in the Group.
- **Weighted Mean (WM).** Employed to calculate the average response for each survey indicator to determine the overall level of proficiency and perceived usefulness.
- **Verbal Interpretation Scale.** A 5-point scale was used to translate the weighted means into qualitative descriptions (e.g., "Very Proficient," "Effective," "Relevant").
- **Pearson Product-Moment Correlation (r):** This inferential statistical tool was used to determine the presence, direction, and strength of the relationship between the demographic profiles and the three research variables.
- **Probability Value (p-value):** A significance level (α) of 0.05 was used as the threshold to decide whether to reject or fail to reject the null hypotheses (H_0).

III. RESULTS

A. Demographic Profile of the Respondents

The demographic distribution of the respondents serves as a baseline for understanding the cohort's composition and group dynamics during the implementation of the logic circuit. To ensure a representative sample, simple random sampling was utilized, drawing from the total population of qualified students.



Demographic Profile of the Respondents

As illustrated in Figure 1, the gender distribution shows a significant majority of Male participants (77.70%) in the sample, while Female students account for 22.30%. This distribution reflects broader national and international trends in technical disciplines, where male enrollment consistently outpaces female enrollment in Information

Technology and engineering-related fields (Cheryan, Master, & Meltzoff, 2015). Despite this imbalance, the research aims to determine if both groups achieve a comparable level of technical competency.

Regarding the laboratory's organizational structure, 13.40% of respondents identified as Group Leaders, whereas the vast majority, 86.60%, served as Group Members. This organizational ratio is common in collaborative engineering education, where small leadership cores manage technical documentation and overall project coordination for a larger team (Borrego, Karlin, McNair, & Beddoes, 2013). This hierarchy ensures that while leadership opportunities are concentrated, the physical implementation—such as the complex wiring of 21 LEDs and the configuration of 74XX series logic ICs—is a collaborative technical effort shared by all participants.

B. Perceived Usefulness of Logic Design Concepts

This domain assesses respondents' perceptions of the analytical and theoretical phases of the logic gate integration project. The results indicate that the Main Campus students perceived the transition from Boolean algebra to functional logic mapping as highly effective for their technical growth.

Table 1. Perceived Usefulness of Logic Design Concepts

Indicators	**Mean**	**Verbal Interpretation**
1. Constructing truth tables for digits 0-9 provided a clear framework for mapping binary inputs to segment outputs.	3.79	Very Effective
2. Using K-maps was an effective tool for simplifying Boolean expressions for segments 'a' through 'g'.	3.60	Effective
3. Applying "Don't Care" conditions (X) helped me understand how to simplify circuits for invalid binary inputs (10-15).	3.43	Effective
4. Deriving Boolean expressions from K-maps increased my ability to translate logic into functional diagrams.	3.65	Effective
5. The process of segment activation analysis improved my logical reasoning.	3.73	Very Effective
Overall Weighted Mean	3.64	Effective

As shown in Table 1, the overall weighted mean of 3.64 indicates that students found the logic design phase highly effective in their laboratory training. The highest individual mean was recorded for constructing truth tables (3.79), indicating that students valued the structured framework for mapping decimal digits 0-9 to binary inputs. The application of segment activation analysis (3.73) also received a "Very Effective" rating, which suggests that the cognitive process of identifying which LEDs light up for specific button inputs significantly improved their logical reasoning.

While the use of "Don't Care" conditions (3.43) had the lowest relative mean in this section, it still falls within the "Effective" range, suggesting that students successfully grasped how to optimize circuits by accounting for invalid binary states (inputs 10-15). This theoretical foundation is essential for minimizing the number of logic gates required in physical implementation (Mano & Kime, 2015).

C. Enhancement of Technical Proficiency

This section evaluates the development of the students' hands-on skills during the physical implementation of the logic circuit. The data demonstrates that the Main Campus cohort achieved a high level of proficiency in translating theoretical diagrams into functional hardware.

Table 2. Enhancement of Technical Proficiency

Indicators	Mean	Verbal Interpretation
1. Using 74XX Series Logic ICs enhanced my knowledge of hardware components.	3.64	Proficient
2. The physical wiring of 21 LEDs on a breadboard improved my precision in hardware assembly.	3.48	Proficient
3. Implementing the 9V battery and voltage regulator taught me essential skills in power management.	3.65	Proficient
4. Setting up four push buttons for binary inputs (A, B, C, D) helped me understand digital input-output interfaces.	3.80	Very Proficient
5. The testing and troubleshooting phase improved my problem-solving skills.	3.75	Very Proficient
Overall Weighted Mean	3.67	Proficient

As shown in Table 2, the overall weighted mean of 3.67 indicates that students achieved a solid level of technical competency. The highest level of proficiency was recorded in setting up push-button interfaces (3.80), suggesting that students effectively mastered the concept of digital input-output interaction. The testing and troubleshooting phase (3.75) also received a "Very Proficient" rating.

This highlights that Main Campus students were particularly successful at diagnosing circuit errors by comparing their physical LED outputs with their established truth tables. While the physical wiring of 21 LEDs (3.48) presented the greatest manual challenge, it remained within the "Proficient" range.

The integration of 74XX series ICs (3.64) and power management systems (3.65) further solidifies the students' ability to handle standard industrial hardware components, a skill essential for future coursework in embedded systems and computer architecture (Floyd, 2014).

D. Professional and Career Relevance

This domain assesses the long-term value that students place on hardware-related competencies for their future roles as Information Technology professionals.

The data indicate that students at the Main Campus recognize a strong connection between these laboratory activities and their future career trajectories.

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Table 3. Professional and Career Relevance

Indicators	Mean	Verbal Interpretation
1. Mastery of logic gate integration (AND, OR, NOT, etc.) is a fundamental skill for my future IT career.	3.74	Very Relevant
2. The design-to-construction cycle increased my confidence in handling complex technical projects.	3.53	Relevant
3. The ability to document circuit results (narratives and images) is a professional skill I can use in the industry.	3.70	Very Relevant
4. Understanding 7-segment display logic provides a foundation for learning advanced digital systems.	3.88	Very Relevant
5. I find this hands-on implementation more useful than theoretical learning alone for my technical growth.	3.78	Very Relevant
Overall Weighted Mean	3.73	Relevant

As shown in Table 3, the overall weighted mean of 3.73 confirms that the respondents view the logic gate integration project as highly relevant to their professional development. The highest individual mean in this category—and the entire study—was recorded for understanding 7-segment display logic as a foundation for advanced systems (3.88). This suggests that students clearly perceive the direct progression from basic logic gates to more complex digital architectures, such as microcontrollers and integrated systems. Furthermore, the strong agreement regarding the value of technical documentation (3.70) and hands-on implementation (3.78) aligns with industry standards that prioritize practical troubleshooting and the ability to accurately record technical processes. While the increase in confidence (3.53) received a slightly lower mean, it remains firmly in the "Relevant" category, reinforcing the idea that project-based learning is a significant driver of student self-efficacy in technical fields (Prince, 2004). This comprehensive recognition of career utility highlights the effectiveness of the Main Campus curriculum in preparing students for the rigorous demands of the global technology sector.

E. Summary of Research Domains

This section provides a holistic overview of the findings across the three primary research domains: Logic Design Concepts, Technical Proficiency, and Professional and Career Relevance. By synthesizing the weighted means from the preceding tables, the researchers can evaluate the overall impact of the logic circuit integration project on the one hundred twelve (112) BSIT students at the Main Campus.

Table 4. Summary of Weighted Means for the Research Domains

Research Domain	Weighted Mean	Verbal Interpretation
1. Perceived Usefulness of Logic Design Concepts	3.64	Effective
2. Enhancement of Technical Proficiency	3.67	Proficient
3. Professional and Career Relevance	3.73	Relevant
Grand Weighted Mean	3.68	Proficient / Relevant

Volume: 05 / Issue: 03 / 2026 - Open Access - Website: www.mijrd.com - ISSN: 2583-0406

As summarized in Table 4, the Grand Weighted Mean of 3.68 indicates a high level of achievement and satisfaction among the Main Campus respondents. The data reveal a progressive trend in student perceptions, with Professional and Career Relevance (3.73) receiving the highest rating among the three categories. This suggests that while students found the theoretical design (3.64) and the physical construction (3.67) to be effective and proficient, respectively, they placed the greatest value on the long-term utility of these skills for their future IT careers. This hierarchy of results indicates that students can look beyond the immediate challenges of K-map simplification or the manual complexity of wiring 21 LEDs on a breadboard to recognize the foundational importance of these tasks for advanced digital systems. The consistent scores across all domains demonstrate that the Main Campus curriculum successfully balances theoretical depth with practical application, ensuring that BSIT students graduate with a well-rounded technical competency that meets the rigorous demands of the global technology industry (ACM, 2017; Prince, 2004).

F. Correlation Analysis of Demographic Profile and Research Variables

This section evaluates the potential relationship between the demographic profiles (Sex and Role) of the one hundred twelve (112) respondents and their respective assessments of the logic gate integration project at the Main Campus. The statistical analysis was performed using a significance level (α) of 0.05.

Table 5. Correlation Matrix: Demographic Profile vs. Research Variables

Profile Variable	Statistical Value	Usefulness of Design Concepts	Technical Proficiency	Career Relevance
Sex	R	-.120	-.139	-.027
	P	.206	.143	.777
Role in Group	R	-.077	-.169	-.133
	P	.419	.075	.162

The correlation results summarized in Table 5 indicate that respondents' perceived technical competency is largely independent of their demographic background. Specifically, the p-values for Sex in relation to Usefulness (0.206), Proficiency (0.143), and Relevance (0.777) are all significantly higher than the 0.05 alpha level. This demonstrates that the acquisition of technical skills—including the complex wiring of 21 LEDs and the integration of 74XX-series logic ICs—remained consistent regardless of the respondent's gender. Similarly, the p-values for Role in Group (Leader vs. Member) regarding Usefulness (0.419), Proficiency (0.075), and Relevance (0.162) also exceed the threshold for statistical significance. This suggests that the practical experience of troubleshooting physical circuits and simplifying Karnaugh Maps provided equal learning value to both group leaders and members alike. Furthermore, the Pearson values, ranging from -0.169 to -0.027, indicate a very weak to negligible negative correlation between these demographic factors and the research variables.

Based on the statistical evidence presented in Table 5, the researchers fail to reject the Null hypothesis. The results confirm that the demographic profiles of the BSIT students at the Main Campus 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 serves as an equitable and effective pedagogical tool for all students, ensuring that technical competency is achieved uniformly across the cohort.

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Volume: 05 / Issue: 03 / 2026 - Open Access - Website: www.mijrd.com - ISSN: 2583-0406

IV. CONCLUSION

Based on the empirical findings of the study conducted at the Main Campus, the following conclusions are drawn relative to the specific research objectives:

The respondent profile shows a significant gender gap, with males comprising 77.70% of participants and females 22.30%. Furthermore, the laboratory organizational structure is predominantly composed of group members (86.60%) who operate under a smaller subset of group leaders (13.40%).

Students perceive the analytical phase of the project as highly effective, particularly in providing a structured framework for digital logic mapping. The high ratings for truth table construction (3.79) and segment-activation analysis (3.73) indicate that students successfully mastered the cognitive skills required to translate binary inputs into decimal digits.

The hardware implementation phase significantly improved students' technical competency, yielding an overall proficiency mean of 3.67. The "Very Proficient" ratings for digital input-output interfaces (3.80) and troubleshooting (3.75) demonstrate that students effectively transitioned from abstract logic to functional breadboard assembly and error diagnosis.

Respondents place a high professional value on the design-to-construction cycle, with the foundational understanding of 7-segment display logic receiving the highest mean score of 3.88. This confirms that students recognize the direct career utility of mastering basic logic gates as a prerequisite for learning advanced digital systems and hardware-software integration.

Statistical testing reveals that there is no significant relationship between the respondents' demographic profiles and their technical outcomes. The p-values for Sex (0.206 to 0.777) and Role (0.075 to 0.419) confirm that the logic gate integration project delivers consistent and equitable learning value to all BSIT students, regardless of their gender or group responsibility

V. RECOMMENDATIONS

Based on the findings and conclusions of the study conducted at the NEUST Main Campus, the following recommendations are proposed to further enhance the technical competency and pedagogical framework for BSIT students:

- To address the gender distribution gap of 77.70% males to 22.30% females, the College of Information and Communications Technology (CICT) should actively promote female participation in leadership positions for hardware projects. This ensures an inclusive environment where all students have equal access to management experience.
- Although perceived as effective, the K-map simplification (3.60) and "Don't Care" application (3.43) received the lowest scores in the design domain. Faculty should introduce specialized "Logic Optimization Workshops" to provide deeper mastery of Boolean reduction techniques before physical implementation.

Volume: 05 / Issue: 03 / 2026 - Open Access - Website: www.mijrd.com - ISSN: 2583-0406

- To support the development of technical proficiency in LED wiring (3.48), the curriculum should include hands-on modules on breadboard management and precision wire routing, which are essential for high-density circuit assembly involving 21 LEDs.
- Building on the high proficiency in troubleshooting (3.75), it is recommended to introduce "intentional fault" exercises in which students must diagnose and repair preconfigured circuit errors. This would further sharpen their problem-solving skills in complex digital environments.
- Since students recognized the relevance of professional documentation (3.70), the department should adopt a standardized industry-grade reporting format. This will prepare students for the rigorous documentation requirements of the professional IT industry.
- Given the high career-relevance score (3.73) and the confirmation that demographics do not influence performance, the NEUST Main Campus should maintain and expand these project-based learning activities, as they have proven to be universally effective across the student population.
- Before physical assembly, students should be required to validate their designs using digital simulation software. This "Simulation-to-Breadboard" workflow reduces the risk of hardware damage and ensures the logic is sound before the complex wiring of 74XX series ICs.
- To reinforce skills in 9V power management (3.65), a dedicated safety lecture on voltage regulation and current limiting for LEDs should be integrated. This ensures students understand the hardware constraints and safety protocols of digital electronics.
- It is recommended that the Main Campus host a technical symposium where students can showcase their 7-segment display projects. This encourages peer-to-peer learning and enables the exchange of innovative troubleshooting techniques across cohorts.
- The CICT should continue investing in modern hardware kits, ensuring that every student has access to the latest logic ICs and breadboarding accessories. Providing individual hardware sets during laboratory hours can further boost participants' confidence levels (3.53).

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Multidisciplinary International Journal of Research and Development
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