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# Evaluating the Effectiveness of Interactive Simulator in Enhancing Student Understanding of Microprocessor Learning

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## Abstract

Microprocessor Fundamentals is a core subject in electronics engineering, yet many students struggle to understand its abstract concepts such as arithmetic operations, logic processes, data shifting, and conditional flags (Carry, Zero, Overflow, Negative), particularly when taught using traditional methods. To address this challenge, an interactive microprocessor simulator was developed to allow students to perform basic operations and visualize flag changes through a guided interface with flowcharts and step-by-step instructions. This study involved 80 students from the Diploma in Electronics Engineering (Computer) program at Polytechnic Sultan Idris Shah (PSIS), and data were collected via a questionnaire to measure students' confidence, conceptual understanding, and feedback before and after using the simulator.

The analysis using SPSS version 23.0 showed significant improvements in understanding, practical application, and user satisfaction. The findings indicate that interactive simulators substantially enhance learning outcomes, particularly in technically challenging subjects, by offering a more engaging and accessible educational experience.

**Keywords:** Microprocessor learning, interactive simulator, student understanding, digital education tools, engineering education, visualization, teaching innovation

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## I. INTRODUCTION

Microprocessor technology constitutes a fundamental domain within electronics and computer engineering education. It plays a crucial role in embedded systems, automation, and digital devices. For students in electronics engineering programs, understanding how a microprocessor performs tasks such as arithmetic calculations, logic decisions, and data shifting is essential. However, microprocessor topics are often seen as challenging and abstract, especially when students cannot visualize how each instruction works inside the processor [1], [2].

In most teaching environments, microprocessor concepts are delivered through lectures and static examples in textbooks. These methods may help in

theoretical learning, but they often fail to give students the practical experience they need to apply their knowledge effectively [3]. Without hands-on practice, students may struggle to fully understand how operations like ADD, SUB, AND, OR, or how conditional flags like Carry (C), Zero (Z), Overflow (V), and Negative (N) change during instruction execution. Research has shown that abstract content, when not supported by interactive tools, often leads to low engagement and poor retention among learners [4].

To address this issue, educators have begun to explore the use of interactive digital tools to support teaching and learning. Simulations and virtual labs have shown promise in engineering education as they provide students with a platform to experiment safely and repeatedly until they understand the processes [5]. Interactive simulators are especially

helpful for microprocessor topics, as they allow students to view real-time outcomes of instructions, follow logical sequences, and observe how data flows through registers and memory.

In this research, we present an interactive simulator developed specifically for microprocessor learning. The simulator allows users to perform basic operations, visualize data movements, and understand flag changes. It also provides step-by-step explanations and flowcharts to support student learning. This study aims to evaluate how the simulator affects students' confidence, understanding, and practical application of microprocessor knowledge. By gathering data from 80 students at Polytechnic Sultan Idris Shah (PSIS), we examine how effective the simulator is in supporting the learning process.

## II. LITERATURE REVIEW

Many researchers and educators have explored the use of interactive tools to improve student learning, especially in technical subjects like microprocessors. Traditional classroom methods are often limited when it comes to teaching abstract or process-based topics. As a result, students may find it hard to link theory with real-world application, especially in areas that require step-by-step operations like microprocessor operations such as arithmetic, logical, shift & rotate and instruction execution [6].

Past studies have shown that simulation-based tools can make a positive difference in engineering education. De Jong (2010) explained that when students are allowed to interact with a system, such as a simulator, they are more likely to understand the sequence of actions and develop stronger problem-solving skills [7]. Similarly, Dabbagh and Reo (2015) highlighted that students who learn through visual interaction and guided feedback tend to remember complex processes better than those who only receive lectures or read from textbooks [8].

Interactive simulators have also been used in other subjects, such as digital logic design and computer architecture. These tools allow students to build, test, and troubleshoot circuits or code without needing physical components, reducing cost and risk [9]. In the context of microprocessor learning, visual tools can show real-time updates of registers, memory, and flag status, which helps learners understand what happens after each instruction is executed. According to Chua and Tan (2019), simulators can increase student motivation because they make learning feel more like solving a puzzle or game, rather than memorizing technical terms [10].

Furthermore, studies done in polytechnic settings suggest that students respond well to digital learning tools when they are clearly structured, easy to navigate, and provide instant feedback [11]. These factors are especially important for microprocessor subjects, where immediate understanding of outcomes (e.g., what happens to a flag after an operation) is crucial for mastering the topic. For these reasons, the use of an interactive simulator is seen not only as a supplement to lectures but as a necessary innovation in modern technical education.

## III. PROBLEM STATEMENT

Microprocessor subjects are considered one of the most difficult topics in electronics and computer engineering programs. Many students struggle to grasp how individual instructions are processed by the microprocessor, especially when it comes to understanding how arithmetic and logical operations affect flag registers like Carry (C), Zero (Z), Overflow (V), and Negative (N) [6], [12]. These topics are heavily dependent on the ability to visualize internal processor actions, which is something traditional classroom methods often fail to provide.

Lectures and textbook-based teaching are still the main methods used in many institutions, but they are not always effective for abstract or highly technical subjects. Students are often left trying to memorize operations without understanding the actual data flow or the reasons why certain flags are triggered. According to Moore (2002), students tend to disengage from learning when they cannot see how theory applies in practice [13]. This gap between theory and practice is one of the main reasons why microprocessor learning outcomes remain low in many technical education programs.

Another issue is that most students do not get enough hands-on time with real hardware. Microprocessor kits or development boards are expensive and require setup and supervision, which makes it hard to scale practical sessions to large student groups. As a result, many students finish the course without gaining the skills needed to work with real microprocessor systems [14].

Moreover, while some institutions have started using virtual labs or simulation tools, not all of these tools are user-friendly or focused on microprocessor instruction-level execution. Many are designed for higher-level programming or general logic simulation. There is a lack of specific tools that allow students to directly interact with microprocessor operations in a step-by-step manner while observing the results in real time [15].

Due to these issues, there is a clear need for an educational tool that can provide students with interactive, visual, and guided learning experiences. A simulator that mimics actual microprocessor behaviour while offering immediate feedback could help bridge the gap between theory and practical understanding. This research was conducted to evaluate the effectiveness of such a tool, developed specifically to improve learning in the Microprocessor Fundamentals course at PSIS.

#### IV. OBJECTIVES

1. To assess students' familiarity and confidence levels before and after using the simulator.
2. To evaluate how well this simulator helps students understand arithmetic, logical, shift & rotate operations and conditional flags.
3. To gather student feedback on the usability and usefulness of the simulator.
4. To identify the strengths and areas of improvement for the simulator as a teaching aid.

#### V. RESEARCH QUESTIONS

This study focuses on evaluating the effectiveness of an interactive microprocessor simulator in helping students learn key microprocessor concepts. Based on survey data from 80 students of the Diploma in Electronics Engineering (Computer) program at Polytechnic Sultan Idris Shah (PSIS), and aligned with the intended learning outcomes, the research is guided by the following five main questions:

1. ***To what extent does the simulator improve students' understanding of microprocessor operations and conditional flags?***  
This includes student comprehension of basic operations such as arithmetic (ADD, SUB), logic (AND, OR), and shift/rotate instructions, as well as the function of flags like Carry (C), Zero (Z), Overflow (V), and Negative (N).
2. ***How does the simulator affect students' confidence in solving microprocessor-related problems?***  
This question evaluates whether students feel more prepared and confident after using the simulator compared to before.
3. ***Is there a relationship between how often students use the simulator and their level of understanding or confidence?***  
Using SPSS, this study investigates whether frequent use of the simulator results in better learning outcomes.
4. ***How do students perceive the simulator in comparison to traditional lecture-based teaching methods?***  
This question explores whether students

consider the simulator more effective, engaging, or realistic than conventional classroom learning.

5. ***What feedback does students provide regarding the usability and improvement of the simulator as a teaching tool?***

This includes analysis of open-ended responses on additional features, visual preferences, language options, and overall user experience.

#### VI. IMPORTANCE OF STUDY

Microprocessor courses often present difficulties to students because they involve abstract processes that cannot easily be visualized using traditional teaching methods [1], [3]. Understanding how each instruction works, how data moves through registers, and how flags are affected requires not only theory but also repeated hands-on practice. However, in many classrooms, students do not get enough opportunity for this type of engagement due to time limits, hardware costs, or class size [12], [14].

This study is important because it offers a solution in the form of an interactive simulator, which gives students real-time feedback and visual explanations of how instructions affect the processor. By using this tool, learners can better understand the step-by-step execution of microprocessor instructions. This approach supports different learning styles and makes technical subjects more accessible [4], [6]. The results of this study will help educators evaluate the effectiveness of digital tools in teaching and may influence how microprocessor subjects are taught in the future [5], [10].

#### VII. SCOPE OF STUDY

This study focuses on evaluating the use of the Interactive Simulator for Microprocessor Learning developed specifically for diploma-level electronics engineering students at Polytechnic Sultan Idris Shah (PSIS). The research was limited to students enrolled in the Diploma in Electronics Engineering (Computer) program, and the data was collected from 80 participants who used the simulator during their coursework.

The simulator covers basic microprocessor operations such as arithmetic (ADD, SUB), logic (AND, OR), shift/rotate functions, and visual tracking of condition flags like Carry, Zero, Overflow, and Negative. The scope includes assessing student confidence, practical skills, conceptual understanding, and their perception of the simulator's usefulness. Responses were collected

using Google Forms and analysed using SPSS version 23.0.

The study does not include in-depth programming or real hardware implementation, nor does it cover advanced architectures such as ARM or RISC-V, although these may be explored in future developments [15].

## VIII. LIMITATIONS OF STUDY

Like any research, this study has certain limitations. First, the sample size was limited to 80 students from a single institution, which may not represent all students studying microprocessors across different polytechnics or universities. This limits the generalizability of the findings [7], [13].

Second, the research focused only on the immediate learning outcomes based on self-reported data through surveys. While this provides insight into students' perceptions and confidence levels, it does not measure long-term knowledge retention or real exam performance. Future research could include pre- and post-tests to collect more objective data [8].

Third, the simulator itself was still in its development phase during the study. While students gave positive feedback, many also suggested improvements such as adding more topics, language options (e.g., Bahasa Melayu), and enhanced graphics. These limitations suggest that while the simulator is effective, there is room for further development and broader testing [9], [11].

## IX. RESEARCH METHODOLOGY

### A. Study Design

This study employed a quantitative descriptive design to measure the effectiveness of an interactive simulator developed to support Microprocessor Fundamentals learning [2], [5]. The simulator was integrated into the course syllabus for a period of six weeks. The study aimed to measure students' confidence levels, conceptual understanding, usage frequency, and overall perceptions of the simulator. The research focused on identifying patterns and relationships between simulator usage and learning outcomes [7], [16].

### B. Participants

A total of 80 students enrolled in the Diploma in Electronics Engineering (Computer) program at Polytechnic Sultan Idris Shah (PSIS) participated in the study. Participation was voluntary, and

responses were anonymous. This approach is consistent with prior studies focusing on simulation-based learning in higher education [1], [9].

### C. Research Instruments

The main tool used for data collection was a Google Form questionnaire, which included both closed-ended and open-ended questions. The closed-ended questions were based on a 5-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree," to measure students' perceptions in a structured way. The open-ended questions allowed students to give feedback in their own words, especially suggestions for improvement or other comments about the simulator.

The primary instrument used for data collection was a structured Google Form questionnaire. The questionnaire consisted of two sections:

- Section A: Demographics and prior familiarity with microprocessor concepts
- Section B: Post-simulator evaluation — understanding of operations, flag comprehension, usage frequency, confidence level, and feedback

A 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) was used to quantify responses, a method widely used in engineering education research [6], [8].

Sample items include:

- "I am confident in applying microprocessor instructions after using the simulator."
- "The simulator helped me understand the effect of instructions on condition flags (C, Z, V, N)."

The internal consistency of the questionnaire was validated using Cronbach's Alpha, with a reliability score of 0.949, indicating excellent internal reliability [13].

The questionnaire covered several key sections:

- Demographics (gender, age, program)
- Familiarity with microprocessor concepts before using the simulator
- Understanding of specific operations and flags after using the simulator
- Frequency of simulator usage
- Confidence levels and learning satisfaction
- Usability and additional feature requests

This type of instrument is commonly used in educational research for gathering large amounts of feedback quickly and efficiently [5], [7].

Level of Measurement	Linear Scale
Strongly Disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly Agree	5

**Table 1: Likert Scale Score Values**

#### D. Data Collection and Analysis

A total of 80 valid responses were collected using Google Form. All responses were anonymous and voluntarily submitted by students after using the simulator for several weeks. The data were then exported into SPSS version 23.0 for analysis.

The analysis involved two main stages:

1. Descriptive statistics (frequencies and percentages) were used to summarize demographic information, confidence levels, frequency of usage, and perceived effectiveness.
2. Inferential analysis was used to explore relationships between variables. A Pearson correlation test was applied to see whether there was a significant relationship between simulator usage frequency and confidence level. This statistical method is suitable for identifying linear relationships between two continuous variables [10], [13].

Qualitative responses from open-ended questions were analyzed thematically using a simple coding approach. Common themes such as usability issues, feature suggestions, and language preferences were grouped and summarized to support the quantitative results [11], [15].

All responses were analysed using SPSS version 23.0. Descriptive statistics (mean, frequency, percentage) were used to summarize participant responses [2], [12]. A Pearson correlation test was used to identify the relationship between simulator usage frequency and confidence levels. The correlation coefficient ( $r = 0.95$ ) indicated a strong positive relationship [10].

For open-ended questions, thematic analysis was carried out manually using Microsoft Excel to identify common feedback themes. This method follows the coding approach as demonstrated by Chua and Tan in engineering education analysis [9].

#### E. Finding of the Study

The data collected from 80 students were analysed using Statistical Package for the Social Sciences (SPSS) version 23.0. The findings are presented in

three parts: descriptive analysis, correlation analysis, and open-ended feedback summary. This analysis aims to answer the main research questions regarding the effectiveness of the interactive microprocessor simulator.

No.	Survey Item	Mean Score (1–5)
1	Confidence after using the simulator	4.1
2	Understanding of ADD, SUB, AND, OR	4.2
3	Understanding of conditional flags (C, Z, V, N)	4.0
4	Ease of navigation and usage	4.3
5	Improvement in practical skills	4.2
6	Usefulness of step-by-step flowchart	4.1
7	Accuracy in arithmetic and logic operations	4.1
8	Simulator more effective than lectures	3.9
9	Likelihood to recommend simulator	4.4
10	Realistic learning experience	4.2
11	Application of theory to practice	4.3

**Table 2: Effectiveness of the Interactive Microprocessor Simulator in Supporting Student Learning**

SPSS was used only for quantitative data. For open-ended responses (Q19 & Q20), qualitative thematic analysis was performed manually using coding in Microsoft Excel. The following themes emerged:

- Most requested features:
  - Add more topics (e.g., FIFO, LIFO, STM32)
  - Add tutorial videos or step-by-step guides
  - Support for Bahasa Melayu language
  - Dark mode for better visibility
  - Register and memory performance tracking and progress analytics
- User experience feedback:
  - “Very good application and easy to understand”
  - “More topics should be added”
  - “Please add Bahasa Melayu version”
  - “Great effort, well done”

Overall, student feedback was highly positive, with over 90% recommending improvements rather than criticizing the existing features—indicating that the simulator is functional and beneficial but has room

for enhancement.

Table 2 presents the mean scores obtained from students' responses regarding their experience using the interactive microprocessor simulator. Each item reflects a key aspect of the learning process, such as confidence, understanding, usability, and the ability to apply theoretical knowledge in practice. The mean scores were calculated using SPSS version 23.0 based on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

From the table, it is observed that most items received a mean score above 4.0, indicating a generally positive response from the participants. The highest mean score (4.40) was recorded for "Likelihood to recommend the simulator to others", suggesting that students found the tool valuable and would recommend it to their peers. Similarly, the simulator's ease of use and its ability to help apply theoretical concepts also scored high, with mean values of 4.30 and 4.20 respectively.

The lowest mean score (3.90) was related to the comparison between the simulator and traditional lectures. Although this score still reflects a positive opinion, it shows that a small number of students might still prefer or benefit from traditional teaching methods, or a blended approach. However, the score remains above average, indicating that most students found the simulator to be at least as effective as lectures.

The overall mean score for all items was 4.20, which demonstrates that the simulator is an effective tool in supporting student learning. This is further supported by a high Cronbach's Alpha value of 0.949, confirming that the questionnaire items are reliable and consistent in measuring student perceptions.

In summary, Table 2 shows that the interactive simulator successfully contributed to students' confidence, understanding of microprocessor operations, and practical skills. The findings support previous research on the benefits of using simulation tools in technical education [6], [10], [14].

### F. Technical Description of the Simulator

The interactive microprocessor simulator was developed as a web-based application based on visual-based learning principles [4], [17]. It allows students to execute instructions such as ADD, SUB, AND, OR, SHIFT, and ROTATE on a simulated environment. Key features include:

- Real-time flag update for Carry (C), Zero (Z), Overflow (V), Negative (N)
- Step-by-step instruction execution with

flowchart overlay

- Dark/light mode options for accessibility

A pilot usability test was conducted with a group of 10 students to evaluate the initial interface design, ease of navigation, and simulator responsiveness. Refinements were implemented before full deployment based on student feedback, aligned with usability testing frameworks outlined in Zhao *et al.* [16] and Kumar & Singh [17].



Figure 1: Shows the MicroP Simulator Interface

## X. RESULT

The results of this study were based on quantitative data collected from 80 students of the Diploma in Electronics Engineering (Computer) program at Polytechnic Sultan Idris Shah (PSIS), who used the Interactive Simulator for Microprocessor Learning. The responses were analysed using SPSS version 23.0, focusing on descriptive statistics, correlation analysis, and students' perceptions of the simulator's effectiveness.

### A. Improvement in Student Confidence and Understanding

Majority of students reported an increase in confidence after using the simulator. According to the analysis:

- 67.6% of students felt confident or very confident in understanding microprocessor concepts after using the simulator.
- A majority of participants demonstrated a solid understanding of fundamental operations, including ADD, SUB, AND, and OR, with a mean score of 4.20.
- Conditional flags like Carry, Zero, Overflow, and Negative were better understood by students, reflected by a mean score of 4.00.

### B. Usability and Learning Experience

Ease of use was another key factor that contributed to positive learning outcomes. The simulator received a high usability score:

- 77.5% of respondents agreed or strongly

agreed that the simulator was easy to navigate.

- The flowchart and step-by-step feature received a mean score of 4.10, indicating that the visual guidance supported student understanding.

### C. Practical Application and Skill Development

Students also indicated that the simulator improved their ability to apply theory to practice:

- The mean score for improved practical skills was 4.20.
- The ability to apply theoretical concepts in solving problems also received a high mean of 4.30.
- The accuracy of performing operations using the simulator was rated 4.10, showing that the tool supports correct execution of logic.

### D. Perceived Effectiveness and Recommendation

40% of students felt that the simulator was more effective than traditional lectures (mean = 3.90). The highest rated item was “Likelihood to recommend the simulator”, which scored 4.40 on average. Students also believed that the simulator provided a realistic learning experience, with a mean score of 4.20.

### E. Correlation Analysis

Using SPSS, a Pearson correlation test was conducted to examine the relationship between simulator usage frequency and student confidence. The result was:

**Correlation coefficient ( $r$ ) = 0.95**

This shows a very strong positive correlation, indicating that students who used the simulator more frequently felt significantly more confident in understanding microprocessor topics.

## XI. DISCUSSION

The findings of this study clearly indicate that the Interactive Simulator for Microprocessor Learning was effective in improving student understanding, confidence, and practical application of microprocessor concepts. A majority of students reported high satisfaction with the simulator's features, particularly its step-by-step operation guidance, visual flowcharts, and ease of use.

The mean scores in Table 2 showed that most aspects of student learning received positive ratings, with overall scores above 4.0 on a 5-point scale. This

suggests a strong level of agreement among students that the simulator supported their learning process. The strong Pearson correlation ( $r = 0.95$ ) between frequency of simulator usage and confidence level confirms that active engagement with the tool led to better learning outcomes.

These findings support previous research by Wang [1] and Nguyen [2], who emphasized the benefits of interactive tools in technical subjects. The simulator provided a bridge between theory and practice, allowing students to visualize how microprocessor instructions work and how data is processed in real-time. Students also indicated that the simulator was more engaging than lectures alone, a result consistent with the work of Bonwell and Eison [5], who argued that active learning tools improve retention and comprehension.

Despite these strengths, a few students still preferred traditional methods or suggested that the simulator could be improved by adding more topics, language options (e.g., Bahasa Melayu), and tutorials. These are valid points that highlight the need for continued enhancement of the tool.

## XII. CONCLUSION

This study set out to evaluate the effectiveness of an interactive simulator in enhancing student understanding of microprocessor learning. Based on feedback from 80 students and analysis using SPSS version 23.0, it can be concluded that the simulator had a positive impact on student learning outcomes.

Students reported increased confidence, better understanding of both operations and flag functions, and improved ability to apply theory in practice. The simulator was perceived as user-friendly and engaging, with a notable proportion of students favouring it over conventional lecture-based approaches. The strong correlation between simulator usage and student confidence further confirms the tool's effectiveness.

The research confirms that interactive tools can enhance learning in technical subjects, especially when they allow students to visualize and interact with abstract concepts like data processing and instruction execution.

## XIII. RECOMMENDATIONS

Based on the results of this study, the following recommendations are proposed:

1. Integrate the simulator into the formal teaching process. Lecturers should actively incorporate the simulator into microprocessor lessons to

complement traditional instruction and provide students with hands-on digital experience.

2. Expand simulator content and features. Additional modules should be developed to include advanced topics such as STM32, FIFO/LIFO, and moving data, as requested by students.
3. Include multilingual support since several students requested Bahasa Melayu language options, this feature should be added to support diverse learners and improve accessibility.
4. It is recommended to incorporate tutorial and help guides to support first-time users and enhance independent learning.
5. Introduce performance tracking and analytics. Features that allow students to track their progress or view real-time feedback could help increase motivation and personalize the learning experience.
6. Conduct further studies and future research should involve larger sample sizes and different institutions and may also include pre- and post-tests to objectively measure knowledge improvement over time.




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