

# Design and Development of Bits to Bots: A Contextualized Self-Learning Material in Robotics

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**Abstract:** The rapid advancement of 21<sup>st</sup>-century technology highlights the importance of robotics and programming in Science, Technology, and Engineering (STE) education. In the Philippines, the Department of Education (DepEd) strengthens the K to 12 curriculum to prepare learners for a digital world. However, a critical gap remains; existing instructional materials for Grade 10 STE robotics are largely Western-centric and lack cultural contextualization. To address this, the study “Design and Development of Bits to Bots: A Contextualized Self-Learning Material in Robotics” was developed. It aims to provide culturally relevant, learner-centered materials that improve comprehension and engagement. Grounded in Vygotsky’s Sociocultural Theory, the study emphasizes the role of social interaction, scaffolding, and the Zone of Proximal Development (ZPD) in facilitating learning. The study employed the Taba’s Curriculum Development Model, which emphasizes a grassroots inductive approach that prioritizes learners’ needs and experiences in curriculum design. Furthermore, the material was structured using the 4E’s Instructional Model to promote learning engagement and critical thinking skills. A needs analysis revealed that students struggled most with basic programming tools for microcontrollers. To address this need, the material titled “Bits to Bots” was developed and subjected to expert validation using standard DepEd Evaluation Rating Tool. The results indicate that the material effectively meets the required standards for instructional resources and has strong potential to enhance learners’ understanding of robotics. The study recommends its adoption and further uses to enhance robotics learning outcomes.

**Keywords:** Science Education, STEM, Robotics, Instructional Materials Development, Developmental Research, Central Philippines.

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## I. INTRODUCTION

Robotics education has emerged as a cornerstone of modern Science, Technology and Engineering (STE) program pedagogy, equipping students with critical 21st-century skills such as computational thinking, problem-solving, and collaborative innovation [1]. Robotics education is increasingly recognized as a vital component of modern STE curricula, offering a dynamic and engaging platform for cultivating essential 21st-century skills [2]. Moreover, recent research highlights the potential of robotics education to promote equity and inclusion in STE by engaging students from diverse backgrounds and learning styles [3]. Furthermore, studies have shown that robotics education can enhance students' self-efficacy and confidence in their abilities to succeed in STE-related fields [4]. As a result, many countries have integrated robotics into their educational systems to prepare learners for emerging technological demands [5].

Globally, the rapid advancement of technology has positioned robotics and programming as core competencies for 21st-century learners, aligned with the United Nations

Educational, Scientific and Cultural Organization’s (UNESCO) Sustainable Development Goal 4, which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. UNESCO emphasizes that localized, culturally relevant learning is essential to reduce disparities in access and quality, especially for marginalized and developing contexts, while research confirms that integrating robotics significantly elevates educational quality, builds critical thinking, and prepares learners for future careers [6].

However, the lack of contextualized learning materials tailored to local needs and resource constraints limit effective implementation, particularly in public schools [7]. Most available resources use examples, terminologies, and contexts unfamiliar to learners in developing nations, creating a disconnect that slows comprehension and lowers engagement with abstract concepts such as programming and microcontroller operations [6]. Traditional, standardized learning materials often fail to resonate with students from varied cultural, social, and personal backgrounds, leading to disengagement and hindering effective learning [8].

In the Philippines, the Department of Education (DepEd) has strengthened the K to 12 curriculum, embedding robotics and digital skills within the STE program to align with global standards and national development goals. However, integrating robotics into the science curriculum poses challenges among students [9]. This is because most robotics curricula in Philippine schools rely on Western-centric content, which are often culturally misaligned [10]. Teachers use or create different materials altogether if they perceive that the district- or school-provided materials are lacking in characteristics that they believe will engage students and lead to learning [11]. Research indicates that while contextualized materials significantly enhance engagement, comprehension, and academic performance, their availability remains limited in Philippine classrooms [12]. Jalon and Roleda's (2025) study reveals that robotics remains one of the least mastered areas it is taught as purely abstract theories, without connection to local problems, culture, or community applications, making them irrelevant and hard to grasp [13].

This study responds to these identified gaps by developing culturally relevant robotics learning material that is grounded in the local context of Filipino learners. By embedding familiar examples and localized applications of robotics concepts, the material aims to bridge the disconnect between abstract technical knowledge and learners' real-world understanding.

Furthermore, the proposed development is aligned with the Department of Education's mandate for contextualized learning under DepEd Order No. 21, s. 2019, which emphasizes the importance of adapting instructional materials to suit the sociocultural realities of learners. This policy encourages educators to design learning experiences that are relevant, inclusive, and responsive to the diverse backgrounds of students. Similarly, the Revised K to 12 Curriculum (DepEd, 2023) reinforces the need for flexible and inclusive education that accommodates varying learning needs, promotes equity, and supports 21<sup>st</sup> century skills development.

#### ➤ *Statement of the Problem*

This study aimed to design, develop, and validate Bits to Bots as a learning material for Grade 10 STE learners. Specifically, it sought to answer the following questions:

- What is the needs analysis for developing the instructional material?
- What model could be used to design the instructional material?
- What could be developed to enhance the conceptual understanding of STE learners?

## II. METHODOLOGY

This study used developmental research, guided by the ADD model (Analysis, Design, and Development). It offered a structured approach to creating and assessing instructional materials. The ADD model, which is a modification of the ADDIE model offered a comprehensive framework that directed educators through the essential phases of

instructional design, cultivating the creation of effective and learner-centered educational materials [14-15]. This approach is highly practical, especially for rapid prototyping, which is the objective of this research. The Model provides a systematic framework that ensures instructional materials in robotics are purposeful, learner-centered, and effective.

The study was conducted in a large-sized secondary public school in a highly urbanized city in central Philippines offering the Science, Technology, and Engineering Program for School Year (SY) 2025-2026. The school was one of the pioneering schools that implemented the STE or formerly known as Engineering and Science Education Program (ESEP) (DO 38, s. 2013).

The participants of the study were the Grade 10 STE students and their corresponding Electronics and Robotics Teacher for SY 2025-2026. The student-participants were tapped to answer the pre-test which was used as basis for the development of the material. The Electronics and Robotics teacher also shared her insights and feedback regarding the developed material through the evaluation form. Moreover, the developed material was validated by experts in subject matter and trained in learning material writers.

The diagnostic test was adopted from the assessment sections of the Grade 10 4th Quarter Electronics and Robotics Alternative Delivery Module of one schools' division in northern Philippines. This instrument was validated by experts and was published by the Department of Education. The Content Evaluation for Self-Learning Material (SLM) found in DepEd Order no.001 s.2021 Annex 4.1-A to 4.3-B was utilized to evaluate the developed learning material. The evaluation form had three (3) areas: Area 1- Content, Area 2- Language, and Area 3- Layout and Design.

The validators described any deficiency or error and provided suggestions in each criterion item. They also indicated the percentage of error and computed the overall rating. To pass the evaluation, the material needed to garner a 100% total overall rating. A total overall rating of 61%-99% was categorized as conditionally passed, and for total overall rating of 60% and below was categorized as failed. The instruments utilized in this study were not subjected to a validity check since they were taken from the Grade 10 Fourth Quarter Electronics and Robotics Assessment in ADM, and they had already been quality assured by division content experts. Additionally, the SLM Evaluation Rating Sheet is a standardized tool to evaluate learning resources and was taken from DepEd Order No. 001, series 2021. Furthermore, the student-participants were given a feedback form where they could write their comments, suggestions and recommendations for the improvement of the instructional material.

Prior to the conduct of the study, approval from the authority, specifically from the Schools Division where the study was conducted, as well as the school head of the participating school was secured. Also, an approval from the Institutional Research Committee (IREC) or Institutional Review Board (IRB) was secured. To secure the core

principle of ethical research, consent and assent forms were strictly observed. The least learned competency from the pre-test served as the basis for choosing the specific topic or competency of the Bits to Bots. The constructed learning material was anchored to the ADDIE model instructional design. The validators specialized in Robotics and writing learning materials used the Evaluation Rating Sheet for SLM by DepEd. The rating results and comments were compiled and were used to enhance the developed learning material.

The data analysis using descriptive statistics was conducted on the diagnostic results to identify the least learned competencies. By calculating measures such as mean scores, frequencies, and percentages for each competency, the analysis revealed which specific areas had the lowest performance, thereby highlighting the competencies that required the most instructional attention. A content analysis was used to categorize and interpret common themes, sentiments, or suggestions expressed by respondents in the given Evaluation Rating Tool. The Evaluation Rating Tool had three areas: Area 1- Content; Area 2- Language; and Area 3- Layout and Design. Descriptive statistics were also used to calculate measures such as mean (average) rating, median, mode, range, and standard deviation for each item or category to summarize the overall ratings and variability where 5 (five) was the highest rate and one (1) was the lowest.

The Philippine Health Research Ethics Board (PHREB) sets forth ethical guidelines to ensure the protection of research participants and uphold the integrity of research. Key ethical considerations such as social value, informed consent or assent, vulnerability of the respondents, risks and benefits, privacy and confidentiality, transparency, qualifications of the researcher, justice, and community involvement were highly observed throughout the course of the study.

### III. RESULTS AND DISCUSSION

#### ➤ Analysis of Bits to Bots

The researchers used the assessments from ADM Grade 10 Electronics and Robotics Fourth Quarter Assessment as a diagnostic test which aims to identify the Least Learned Competency of learners in Grade 10 Fourth Quarter Electronics and Robotics. Diagnostic test in education is a preliminary assessment mainly used to detect students' strengths and weaknesses in learning [16]. Orhani and Alija (2026) confirm that diagnostic testing goes beyond its role as an assessment tool - it acts as a formative approach that steers instruction toward meeting students' genuine needs [17]. According to Laña (2023), the least learned competencies were those that require higher order thinking skills [18]. When educators successfully identify the least learned skills, they can develop evidence-based strategies to close gaps.

Table 1 Grade 10 Electronics and Robotics Fourth Quarter Diagnostic Test Report

MELCs	Average Mastery Percentage	Rank
1. Describe the materials used for constructing a robot.	60.71	4
2. Describe the kind of motors to be used in constructing the robot. • Stepper motor • Servo motor	40.71	2
3. Discuss the principle of operation of the motor used for the robot.	79.29	5
4. Name and describe the different sensors used in a robot.	55.71	3
5. Describe some basic programming tools used for the microcontroller in a robot	30.71	1

The table shows the learners' mastery level across five Most Essential Learning Competencies (MELCs) in robotics. The highest mastery was in Discussing the principle of operation of motors with Average Mastery Percentage (AMP) of 79.29. Followed by Describing materials used in constructing a robot (AMP=60.71) and Naming and describing sensors (AMP = 55.71). Lower mastery was observed in Describing kinds of motors (stepper and servo) with AMP of 40.71 and Basic programming tools for microcontrollers with AMP of 30.71, which ranked the lowest. Overall, all competencies fall below the 75% mastery benchmark, meaning learners did not meet the expected proficiency level. The results of diagnostic tests enable teachers to realize whether the intended curriculum is at the level of readiness of students. In case there are many students at the pre-skilled level, the teachers can either slow down or change plans [18].

Teaching and learning computer programming language especially for non-computer science students are challenging [19]. A study by Islam et al. (2019) and Tlale-Mkhize (2025) found that 65% of introductory students struggle to translate logical problems into structured code, with many confusing syntax rules across different

programming languages like C++ (used in Arduino) and Python [16], [20]. Recent investigation in robotics reveals that most of the participants have difficulties in programming [9].

The results reveal that students demonstrate low to near mastery across all robotics competencies, with the greatest difficulty in programming. These findings imply the need for contextualized materials to address learning gaps and improve student performance in robotics education.

#### ➤ Designing Bits to Bots

The design of the developed learning material is anchored on Taba's Curriculum Development Model or the Grassroots Model emphasizing the involvement of teachers and learners in the process, starting with specific learner needs and moving towards broader curriculum framework [14]. A study by Wahyuni et al. [15] shows that the developed Taba model was effective in improving learning outcomes. According to Hatch and Clark [16], instructional planning is an essential foundation for creating an effective, systematic, and goal-oriented learning process.

Furthermore, the researcher developed Bits to Bots following 4E's Instructional Model. The 4E approach presents a propitious field for the challenges of education in the 21st century, especially for the understanding of teaching and learning in socio-material and technological environments, as well as new research tools that support theories of learning with empirical evidence [17]. The 4E's instructional model has emerged as a powerful framework for designing learning materials that foster active, inquiry-based learning [18].

The *Bits to Bots* instructional material is composed of ten structured sections, each designed to support learner understanding, engagement, and mastery of robotics concepts.

- *Introduction*

The Introduction section presents the overall purpose and scope of the material. It provides learners with a clear orientation of what the module is about, including its relevance to robotics education and its expected outcomes. This section helps establish context and prepares learners for the learning journey.

- *Mission Possible*

This section outlines the learning objectives and MELCs (Most Essential Learning Competencies) that the material aims to develop. It clearly states the knowledge, skills, and competencies learners are expected to achieve, serving as a guide for both instruction and assessment.

- *Pretest*

The Pretest functions as a diagnostic tool to assess learners' prior knowledge. It consists of a short set of questions with corresponding answer keys. This allows both teachers and learners to identify strengths and areas that require more focus before proceeding with the lesson.

- *Let's Break it Down*

This section simplifies complex robotics concepts by breaking them into smaller, manageable parts. Concepts are explained step-by-step using clear language, visuals, and examples, making them easier to understand and retain.

- *Beyond the Notes*

Beyond the Notes enriches learning by providing additional information, real-world applications, and extended activities. It encourages learners to go beyond basic concepts and explore broader connections, deepening their understanding of robotics in real-life contexts.

- *Hands on, Minds on*

This section promotes active and experiential learning. It includes activities, exercises, and projects that require learners to apply concepts through hands-on tasks. It develops both technical skills and critical thinking.

- *Let's Zoom in*

The Let's Zoom In section provides focused discussion of key concepts. It highlights important details, clarifies

misconceptions, and ensures that essential ideas are fully understood before progressing.

- *Let's Check*

This section serves as a formative assessment tool. It includes short quizzes, guide questions, or summaries that help reinforce learning and check learner comprehension of previously discussed topics.

- *Post Test*

The Post Test evaluates learners' overall achievement and mastery after completing the module. It measures learning gains and determines whether the objectives outlined in Mission Possible have been met.

- *References*

The References section lists all sources used in developing the material, such as books, journals, and websites. It ensures academic integrity, provides credibility, and allows readers to explore further related information.


Generally, Bits to Bots has three main parts which are the preliminaries, the body and the back matter. The preliminaries include: The Introduction, Mission Possible and Pretest. The body which is the actual 4Es (Explain, Engage, Extend, Examine) is a concrete approach to incorporating research-based practice into daily instruction [18]. It includes Let's Break It Down (explain), Beyond the Notes (engage); Hands On, Minds On and Let's Zoom (extend). Let's Check and Post Test are the Examine. Lastly back matter includes the references and key answers.

➤ *Development of Bits to Bots*

Bits to Bots is developed based on a thorough needs analysis of Grade 10 STE learners. Robotics instruction often requires bridging abstract technical concepts with learners lived experiences, yet current materials may not fully reflect their cultural and environmental contexts. Bits to Bots aims to address this gap by designing instructional material that is localized, learner-centered, and directly connected to students' realities. By doing so, the material anticipates the challenges learners face in understanding robotics and will provide a more accessible, meaningful, and engaging pathway for them to acquire knowledge and skills. Figure 1 shows some key features of Bits to Bots.

## LET'S BREAK IT DOWN

### Basic Programming Tools Used in Microcontrollers for Robots



Robots rely on computer programs to interpret sensor data, think through solutions, and decide on actions. These programs, running on a processor, are fundamentally sets of instructions that transform inputs into desired outputs.

The world of robotics can seem daunting, filled with complex hardware and intricate code. However, the basic programming tools needed to get started with microcontrollers are surprisingly accessible.

#### Sensors in Robotics

Sensors empower robots to perceive and respond to their surroundings. By gathering data about position, distance, pressure, objects, and more, these devices enable robots to move with accuracy, avoid hazards, and execute tasks with precision. They are the key to a robot's ability to act effectively in the real world.

**There are two main types of robotic sensors:**

- Internal sensors** monitor the robot's own state. These include position encoders, torque sensors, and temperature monitors that help control motion, stability, and power.
- External sensors** track the outside world. These include vision systems, proximity sensors, and range sensors used to avoid collisions or identify objects.

**Table 1. Types of Sensors**

Type of Sensors	Main Function	Example
Motion and position	Movement	Encoders, Gyros
Proximity	Avoidance	IR, Ultrasonic
Vision and camera	Seeing	2D or Depth Cameras
Force and torque	Pressure	Force or torque sensors
Range	Distance	LiDAR, Ultrasonic
Tactile and touch	Touch	Pads, Artificial skin
Environmental	Safety	Temp, Gas, Humidity
Sound	Hearing	KY-038, microphones

### Types of Programming Language Diagram

**Low-Level**

Ex: Machine Language, Binary Code

```

10100010101000010101
01110001010100101101
10111101001000010101
01110001010100101101
01110001010100101101
01110001010100101101
01010010110111101001
1011101001000010101
01110001010100101101
1011101001000010101
01110001010100101101
            
```

**High-Level**

Ex: Assembly Language, Add A, Sub B, C, C++

```

void setup() {
  // Set the LED pin a
  pinMode(LED_PIN, OUTPUT);
}

void loop() {
  // Turn the LED on
  digitalWrite(LED_PIN, HIGH);

  // Wait for a second
  delay(1000);

  // Turn the LED off
  digitalWrite(LED_PIN, LOW);
}
            
```

**High-Level**

Ex: Pascal, Python, Java

```


javascript ~
const fruits = ["Apple", "Banana", "Orange"];

console.log("List of fruit");


// Using a for...of loop (
for (const fruit of fruits)
  console.log(fruit);
)

// Alternatively, using a
for loop
            
```


### BEYOND THE NOTES




In this activity, we will try to do the same programming but remember this is for our activity only. Below are sets of objects that represents the different commands we want for our robot to perform.




Walk Straight for 1 minute




Walk Straight for 3 minutes




Walk Straight for 5 minutes



Stop



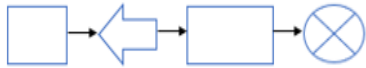
Turn Right



Turn Left


Direction: Draw inside the box the program of the given commands by connecting the correct objects in a series using an arrow line. Study the sample below.

Sample Command: Walk for 1 minute, then turn left and walk for 3 minutes then stop.

Answer: 

1. Walk for 3 minutes, turn left and walk for 1 minute then stop.
2. Walk for 5 minutes and stop.
3. Walk for 8 minutes, then turn right and walk for 1 minute and stop.

## HANDS ON, MINDS ON



**Directions:** Build a robot and program it to perform the task below using different coding type: Icon Block, Word Block, and Python. You will be rated based on the rubrics provided below.

CRITERIA	ADVANCE -10	PROFICIENT - 8.5	BASIC - 7
Build Robot	Student skillfully assembles the robot	Successfully assembles the robot with some outside help	Struggles to assemble the robot
Programming	Student successfully reprograms the robot to achieve more complex challenges	Reattempts to reprogram the robot to achieve more complex challenges	Student was able to run pre-made program
Dismantle the robot and organize the bin	Student accurately dismantles the robot and organized the bin	Dismantles the robot and organized the bin proficiently	Does not effectively dismantle the robot and organize the bin
Time on task	Task was able to finish adequately and was never off task	Able to finish the task in allowable time and was off task at least once	Was able to finish the task with allowable time and was off the task for 2-3 times
Number of challenges completed	Completed all tasks and programs	Was able to finish most of the task	Some tasks were undone

Fig 1 Images of Key Features of Bits to Bots

The development of Bits to Bots is based on the needs of the learners. During the development phase, the quality of Bits to Bots was validated by experts using the Content Evaluation for SLM Evaluation Sheet to ensure its alignment with curriculum standards, cultural relevance, and pedagogical soundness. Expert validation confirmed that the material is not only technically accurate but also innovative in its contextualized design. The Evaluation Rating Tool has three areas which are the content, language and layout and design.

Table 2 presents the expert evaluation results of the Bits to Bots instructional material using the DepEd evaluation criteria across six key factors. The findings reveal that Factor I (Most Essential Learning Competencies) obtained a perfect average rating of 40 (100%), indicating that the material is highly aligned with prescribed competencies. Similarly, Referencing and Source Citation (Factor VI) also achieved a perfect score of 5, demonstrating strong adherence to academic standards. Other factors such as Instructional

Quality of Text and Visuals (m=19.60) and Instructional Design and Organization (m=18.96) received high ratings, while Assessment (m=9.48) and Readability (m=4.80) also fell within acceptable ranges. The overall weighted mean of 97.84 led to a “Conditionally Passed” recommendation, suggesting that while the material meets most standards, minor revisions may still be necessary.

Table 2 Content Evaluation Results

Criteria	Ave Rate
Most Essential Learning Competencies (40%)	40.00
Instructional Design and Organization (20%)	18.96
Instructional Quality of Text and Visuals (20%)	19.60
Assessment (10%)	9.48
Readability (5%)	4.80
Referencing and Source Citation (5%)	5.00
TOTAL (100%)	97.84

Note: Recommendations are determined based on the computed weighted results: 100% =Passed(P), 61%-99%=Conditionally Passed (CP), and 60% and below=Failed(F).

These results imply that the instructional material is generally effective, well-structured, and aligned with curriculum standards, but still requires slight enhancement particularly in assessment strategies and clarity to achieve full acceptability. High ratings in content alignment and instructional quality indicate that the material can support meaningful learning, while the slightly lower scores in assessment suggest the need for improved evaluation techniques to better measure learner understanding.

Research consistently shows that materials strongly aligned with learning competencies lead to improved student outcomes and more efficient curriculum delivery [26]. The inclusion of proper referencing and citation within instructional materials is paramount for establishing credibility and upholding academic integrity. This practice not only prevents plagiarism but also fosters critical thinking and respects intellectual property, thereby enhancing the overall educational value and trustworthiness of the learning resources [27]. Supporting literature emphasizes that well-designed instructional materials must ensure alignment with competencies, clear organization, and appropriate assessment to promote effective learning outcomes.

Table 3 on Language Evaluation Results present a perfect level of agreement among the five evaluators across all criteria. Specifically, Coherence and Clarity of Thought (35%), Grammar and Syntax (35%), Spelling and Punctuation (10%), and Consistency in Style (20%) all obtained perfect scores, resulting in an overall average rate of 100%. This indicates that the Bits to Bots instructional material demonstrates excellent language quality, characterized by clear organization of ideas, correct grammatical structures, accurate spelling and punctuation, and consistent stylistic presentation. Consequently, the evaluators unanimously rated the material as “Passed,” reflecting full compliance with language standards required for instructional resources.

Table 3 Language Evaluation Results

Criteria	Ave Rate
Coherence and Clarity of Thought (35%)	35
Grammar and Syntax (35%)	35
Spelling and Punctuation (10%)	10
Consistency in Style (20%)	20
TOTAL (100%)	100

Note: Recommendations are determined based on the computed weighted results: 100% =Passed(P), 61%-99%=Conditionally Passed (CP), and 60% and below=Failed(F).

These results imply that the material is highly readable, comprehensible, and accessible to learners, which is essential for effective knowledge transfer. High coherence and clarity suggest that learners can easily follow and understand complex robotics concepts, while strong grammar and syntax ensure that there are minimal barriers to comprehension. In addition, consistency in style contributes to a more professional and engaging learning experience.

Research indicates that the readability of texts has a direct and significant effect on students’ reading comprehension, as differences in text readability lead to variations in comprehension performance and processing time. Zainurrahman et al. (2024) found that variations in text readability levels resulted in significant differences in students’ reading comprehension and processing time, highlighting that more readable texts lead to better understanding of content [28].

Similarly, Day et al. (2024) reported that improvements in text formatting and readability increased learners’ comprehension and reading efficiency, emphasizing that well-presented instructional materials contribute to improved academic performance [29]. Overall, these studies collectively support the assertion that instructional materials characterized by high readability and proper organization significantly improve learners’ understanding and retention.

The data in Table 5, Layout and Design Evaluation, indicate that the Bits to Bots instructional material obtained a very high overall average rating of 99.48%, reflecting strong acceptability in terms of visual and structural design. Among the criteria, Factor I (Physical Attributes) received a perfect average score of 35, indicating that the material’s physical presentation such as layout clarity, spacing, and visual appeal fully met evaluation standards. Factor III (Visuals) also achieved a high mean score of 34.72, demonstrating that illustrations, graphics, and visual aids effectively supported the instructional content. Meanwhile, Factor II (Format) obtained a slightly lower but still high mean of 29.76, suggesting minor areas for improvement in formatting consistency. Despite the minor variations in evaluator ratings, the overall recommendation was “Conditionally Passed,” indicating that the material is highly acceptable but may require minimal refinement.

Table 4 Layout and Design

Criterion	Ave Rate
Physical Attributes (35%)	35.00
Format (30%)	29.76
Visuals (35%)	34.72
TOTAL (100%)	99.48

Note: Recommendations are determined based on the computed weighted results: 100% =Passed(P), 61%-99%=Conditionally Passed (CP), and 60% and below=Failed(F).

These findings imply that the instructional material is visually effective, learner-friendly, and well-structured, which are essential qualities for enhancing engagement and comprehension. Studies also indicate that effective instructional design, including the use of appropriate visuals and organized formats - significantly contributes to improved student engagement and academic performance [30]. High ratings in physical attributes and visuals suggest that the material successfully captures learners’ attention and facilitates understanding of complex robotics concepts through visual representation. However, the slightly lower score in format indicates that improvements in layout consistency or organization may further optimize clarity and usability. From an instructional perspective, effective layout and design reduce cognitive overload and enable learners to process information more efficiently, thereby improving learning outcomes. Furthermore, research shows that visual elements and structured design enhance learners’ ability to process and retain information by supporting cognitive processes such as organization and integration of knowledge [31]. In general, the best materials are simple, clean, and straightforward.

Table 5 shows the Evaluation Rating Tool Summary presenting the overall results of the validation of the Bits to Bots instructional material across three major areas: content, language, and layout and design. The findings show that Area 2 – Language obtained a perfect score of 100% with a “Passed” recommendation, indicating excellent quality in terms of clarity, grammar, and coherence. Meanwhile, Area 3 – Layout and Design achieved a very high rating of 99.48%, and Area 1 – Content received 97.844%, both categorized as “Conditionally Passed.” These results indicate that while the material demonstrates a very high level of acceptability across all criteria, minor revisions are suggested in content and layout to further enhance its overall quality.

Table 5 Evaluation Rating Tool Summary

Area	Rate	Recommendation
Area 1 – Content	97.84%	Conditionally Passed
Area 2 – Language	100%	Passed
Area 3 – Layout and Design	99.48%	Conditionally Passed

The results imply that Bits to Bots material is highly effective, well-developed, and suitable for instructional use, particularly due to its strong language quality, which ensures clarity and ease of comprehension. The near perfect scores in content and design further suggest that the material is aligned

with curriculum standards and visually supportive of learning. The alignment with MELCs (100%) is particularly noteworthy, confirming their direct relevance to the curriculum. However, the “conditionally passed” ratings indicate the need for refinement in content accuracy, organization, or formatting to achieve optimal instructional effectiveness.

A study by Eviota et al. (2026) found that learning materials rated "very satisfactory" or higher on standardized evaluation tools led to a 28% increase in student mastery of targeted competencies compared to materials with lower scores [32]. According to McKenney & Reeves (2021), while the materials have garnered high scores, the presence of “Conditionally Passed” recommendations suggests that while the materials are effective, further refinement in areas like instructional design consistency, assessment clarity, and visual integration could further elevate their quality [33]. As educational systems continue to emphasize quality and equity, high performance on evaluation tools will remain a key indicator of effective learning material development.

#### IV. CONCLUSION

Based on the findings, the study concludes that addressing learning gaps is crucial, as students encounter significant difficulties in understanding programming and microcontroller concepts, thereby necessitating the development of specialized instructional materials that simplify these complex topics. Furthermore, the development of Bits to Bots effectively addresses the problem of Western-centric and non-contextualized resources, making robotics education more relatable and engaging for Filipino learners. In this way, Bits to Bots stands out as a future instructional innovation - one that will empower Grade 10 STE learners to excel in robotics while remaining rooted in their own culture and environment.

The utilization of systematic frameworks ensures that the material is developed logically, aligned with curriculum standards, and responsive to the learners’ Zone of Proximal Development (ZPD).

#### RECOMMENDATIONS

It is highly recommended that learners maximize the use of the "Bits to Bots" learning material to facilitate independent study and achieve mastery of the difficult concepts in Robotics, specifically in programming and microcontrollers. The material is designed to be culturally relevant, logically sequenced, and easy to understand, thereby reducing the cognitive load often associated with technical topics. Furthermore, utilizing this resource encourages learners to develop higher-order thinking skills, specifically critical thinking and problem-solving abilities, which are essential competencies in the 21st-century learning landscape.

Science and Robotics teachers are strongly encouraged to adopt and integrate "Bits to Bots" into their daily instructions to effectively address identified learning gaps, particularly in the area of programming tools and

microcontrollers. The material serves as a valuable pedagogical resource that complements various teaching strategies, providing a structured framework that makes complex and abstract topics more accessible, concrete, and engaging for students. Its use can also assist teachers in facilitating differentiated instruction, ensuring that learning is responsive to the diverse needs and pace of the learners. The novelty of Bits to Bots lies in its ability to transform robotics into a subject that learners can confidently navigate, using localized examples, scenario-based activities, and learner-centered tasks. This progression highlights how contextualization can serve as a powerful instructional strategy to elevate proficiency levels.

Curriculum planners and developers are recommended to consider the design, structure, and methodology employed in "Bits to Bots" as a viable model for creating localized and contextually responsive instructional materials. According to Almerino et al., 2020, with high evaluation ratings are prioritized for district-wide implementation in Philippine public schools, ensuring equitable access to effective resources [34].

Future researchers are recommended to build upon the findings of this study by replicating it in different schools, divisions, or regions to validate its effectiveness across various learning contexts. They may also expand the scope of the study to cover other competencies and topics in Electronics and Robotics. Additionally, researchers are encouraged to explore the development of supplementary learning tools and multi-modal resources, such as interactive applications, simulation software, and video tutorials, which can be integrated with "Bits to Bots" to further enhance student engagement, interactivity, and learning outcomes.

## REFERENCES

- [1]. Samiur Rahman Khan, Nadeem Hossain, and Zahid Karim Ullah, "The Role of Robotics in Enhancing STEM Learning for Young Learners," *Proceeding Int. Conf. Innov. Sci. Technol. Educ. Child.*, vol. 4, no. 2, pp. 321–324, 2024, doi: 10.62951/icitech.v4i2.131.
- [2]. M. M. Maruf, T. Bhuiyan, E. J. Eshita, M. S. Hossen, and M. H. Imran, "An IoT-based smart home automation system: Enhancing security, energy efficiency, and remote accessibility," *Multidiscip. Sci. J.*, vol. 8, no. 7, 2026, doi: 10.31893/multiscience.2026262.
- [3]. C. Jackson *et al.*, "Equity-Oriented Conceptual Framework for K-12 STEM literacy," *Int. J. STEM Educ.*, vol. 8, no. 1, 2021, doi: 10.1186/s40594-021-00294-z.
- [4]. R. Kelly and M. Allen, *Exploring Engagement and Self-Efficacy in an Introductory Computer Science Course*, vol. 1, no. 1. Association for Computing Machinery, 2023. doi: 10.1145/3622780.3623649.
- [5]. M. Ryalat, N. Almtireen, G. Al-refai, H. Elmoaqet, and N. Rawashdeh, "Research and Education in Robotics: A Comprehensive Review, Trends, Challenges, and Future Directions," *J. Sens. Actuator Networks*, vol. 14, no. 4, pp. 1–40, 2025, doi: 10.3390/jsan14040076.
- [6]. UNESCO, "Education for sustainable development | UNESCO," *Education for sustainable development*, 2023. <https://www.unesco.org/en/sustainable-development/education> (accessed May 30, 2026).
- [7]. J. D. B. Llabore, "Readiness of the Public Junior High Schools in the Province of Albay Offering Robotics: An Assessment," *Int. J. Sustain. Adv. Integr. Res.*, vol. 2, no. 2, pp. 200–207, Apr. 2026, doi: 10.65339/IJSAIR.V2.I2.179.
- [8]. Y. Assefa, S. A. Tilwani, B. T. Moges, H. Majeed, and A. A. Alhur, "Bridging the gaps: Addressing challenges of student learning outcomes through innovative and culturally relevant approaches in pastoral areas," *Soc. Sci. Humanit. Open*, vol. 12, p. 101822, Jan. 2025, doi: 10.1016/J.SSAHO.2025.101822.
- [9]. R. A. Bantigue and L. G. Baraquia, "Coping with the Challenges of the Integration of Robotics in the Science, Technology, and Engineering Program and Influences to Students' Multiple Intelligences," *Int. J. Acad. Multidiscip. Res.*, vol. 7, no. 8, pp. 85–95, 2023, doi: 10.2139/ssrn.4832701.
- [10]. M. J. A. Santiago and V. C. Naval, "Evaluation of Robotics Education Program among Private Secondary Schools in Region IV-A CALABARZON," *Int. J. Sustain. Adv. Integr. Res.*, vol. 2, no. 1, pp. 721–729, Mar. 2026, doi: 10.65339/IJSAIR.V2.I1.89.
- [11]. E. L. Wang *et al.*, "Teachers' Perceptions of What Makes Instructional Materials Engaging, Appropriately Challenging, and Usable: A Survey and Interview Study," RAND Corporation, Santa Monica, California, Jan. 2021. doi: 10.7249/RR134-2.
- [12]. J. Dohinog *et al.*, "Utilization of Contextualized Instructional Materials in Education: A Systematic Review," *Psychol. Educ. A Multidiscip. J.*, vol. 44, no. 2, pp. 203–214, Aug. 2025, doi: 10.70838/PEMJ.440203.
- [13]. J. B. Jalon and L. S. Roleda, "Building beyond the robot: Disciplinary integration in challenge-based learning," *J. Inf. Technol. Educ. Res.*, vol. 25, p. 10, 2026, doi: 10.28945/5747.
- [14]. E. A. Trif-Boia, "INSTRUCTIONAL DESIGN MODELS FOR TECHNOLOGY INTEGRATION IN THE CLASSROOM," in *Proceedings of ADVED 2023- 9th International Conference on Advances in Education*, Oct. 2023, pp. 25–31. Accessed: May 30, 2026. [Online]. Available: [https://www.ocerints.org/adved23\\_e-publication/papers/Elena Andreea Trif-Boia.pdf](https://www.ocerints.org/adved23_e-publication/papers/Elena Andreea Trif-Boia.pdf)
- [15]. A. Özkan, İ. Çevik, E. Saylan, and Ü. Çakıroğlu, "The Past and Present of Instructional Design in Online Learning: Trends and Emerging Directions," *Int. Rev. Res. Open Distrib. Learn.*, vol. 26, no. 3, Aug. 2025, Accessed: May 30, 2026. [Online]. Available: <https://www.irrodl.org/index.php/irrodl/article/view/8507/6287>
- [16]. N. Islam, G. Shafi Sheikh, R. Fatima, and F. Alvi, "A Study of Difficulties of Students in Learning Programming," *J. Educ. Soc. Sci.*, vol. 7, no. 2, pp. 38–46, 2019, doi: 10.20547/jess0721907203.

- [17]. S. Orhani and S. Alija, "Using diagnostic testing to build effective teaching strategies in mathematics," *Int. J. Didact. Stud.*, vol. 7, no. 3, p. e39019, Mar. 2026, doi: 10.33902/IJODS.202639019.
- [18]. G. Laña, "Least Learned Competencies in Mathematics 8: Basis in Crafting Strategic Intervention Materials," *J. Res. Investig. Educ.*, pp. 75–81, Oct. 2023, doi: 10.37034/RESIDU.V1I3.158.
- [19]. R. Pascual, N. Bravo, and C. Quiñones, "FLEXIBLE TACTICS TO FACE COVID-19 AND SOCIAL OUTBREAK IN CHILE," Jun. 2021. Accessed: May 30, 2026. [Online]. Available: <https://www.cdio.org/sites/default/files/documents/138..pdf>
- [20]. M. Tlale-Mkhize, "Challenges Experienced by First-Year Students in the Programming Module-A Literature Review," *J. Educ. Learn. Technol.*, vol. 6, no. 12, pp. 2025–1555, 2025, doi: 10.38159/jelt.202561224.
- [21]. H. Tanjung and A. Ramli, "Curriculum Development Model," *Mudarris J. Islam. Teach. Learn.*, vol. 1, no. 1, pp. 23–32, 2025, Accessed: May 30, 2026. [Online]. Available: <https://ejournal.stit-syekhburhanuddin.ac.id/index.php/mudarris/article/view/134>
- [22]. L. Wahyuni, W. Warsiman, S. S. Adi, and W. Goeyardi, "Redesigning Taba's model in learning literature based on learning freedom principle to improve the ability to appreciate poetry," *Cogent Educ.*, vol. 12, no. 1, Dec. 2025, doi: 10.1080/2331186X.2025.2485527.
- [23]. L. Hatch and S. K. Clark, "A study of the instructional decisions and lesson planning strategies of highly effective rural elementary school teachers," *Teach. Teach. Educ.*, vol. 108, p. 103505, Dec. 2021, doi: 10.1016/J.TATE.2021.103505.
- [24]. R. Videla and T. Veloz, "The 4E Approach Applied to Education in the 21st Century," *Constr. Found.*, vol. 18, no. 2, 2023, Accessed: May 30, 2026. [Online]. Available: <https://constructivist.info/18/2/153>
- [25]. T. Scheiner, E. Aspbury-Miyaniishi, and D. Jazby, "Beyond traditional cognitivist boundaries: Reconceptualizing teacher noticing through 4E cognition," *Teach. Teach. Educ.*, vol. 180, p. 105606, Oct. 2026, doi: 10.1016/J.TATE.2026.105606.
- [26]. S. Kurt, "How Can We Align Learning Objectives, Instructional Strategies, and Assessments?," *Educational Technology*, Nov. 2020. <https://educationaltechnology.net/how-can-we-align-learning-objectives-instructional-strategies-and-assessments/> (accessed May 30, 2026).
- [27]. R. Enciso and D. C. Bueno, "Upholding Academic Integrity: Strategies for Fostering Plagiarism Awareness and Prevention among MAEd Science Education Students," *Institutional Multidiscip. Res. Dev. J.*, vol. 7, no. 8, pp. 440–455, 2024.
- [28]. Zainurrahman, F. N. Yusuf, and D. Sukyadi, "Text readability: its impact on reading comprehension and reading time," *J. Educ. Learn.*, vol. 18, no. 4, pp. 1422–1432, Nov. 2024, doi: 10.11591/EDULEARN.V18I4.21724.
- [29]. S. L. Day, N. Atilgan, A. E. Giroux, and B. D. Sawyer, "The Influence of Format Readability on Children's Reading Speed and Comprehension," *Educ. Sci.*, vol. 14, no. 8, p. 854, Aug. 2024, doi: 10.3390/EDUCSCI14080854/S1.
- [30]. J. Regondola and J. M. Astorga, "Effect of Implementing Visual Learning Materials on Academic Engagement Among Grade 6 Students," *J. Arts, Humanit. Soc. Sci.*, vol. 2, no. 2, pp. 256–264, Aug. 2025, doi: 10.69739/JAHSS.V2I2.767.
- [31]. N. J. Hunsu, O. Adesope, and M. T. McCrudden, "The effects of text structure on students' use of comprehension strategies and cognitive outcomes during science text processing," *Front. Educ.*, vol. 8, p. 1112804, Apr. 2023, doi: 10.3389/FEDUC.2023.1112804/TEXT.
- [32]. M. P. Eviota, M. L. Estoque, E. A. Borja, E. P. Patulin, C. P. Mosa, and K. M. Ngilangil, "Development of Least Learned Competencies-Based Intervention Materials for Elementary," *Int. J. Innov. Sci. Res. Technol.*, p. 2173, Jan. 2026, doi: 10.38124/IJISRT/26JAN684.
- [33]. S. McKenney and T. C. Reeves, "Educational design research: Portraying, conducting, and enhancing productive scholarship," *Med. Educ.*, vol. 55, no. 1, pp. 82–92, Jan. 2021, doi: 10.1111/MEDU.14280;REQUESTEDJOURNAL:JOURNAL:13652923.
- [34]. P. M., Almerino, J. G. F., Mamites, I. O., Pinili, L. C., Tenerife, J. J. L., Sitoy, R. E., Abelgas, L. J., & Peteros, E. D. "Evaluating the Academic Performance of K-12 Students in the Philippines: A Standardized Evaluation Approach," *Education Research International*, 2020(8877712),.1–8. Oct. 2020, doi:10.1155/2020/8877712