ISSN 3047-5473
Innovation in Engineering, Vol 3, No 1, 2026, pp. 24-54

Developing a robotics-based advocacy framework for electronics engineering using an integrated KANO–IPA–QFD approach

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Received: 23 December 2025; *Revised*: 14 February 2026; *Accepted*: 20 February 2026

https://doi.org/10.58712/ie.v3i1.47

Abstract: Electronics Engineering (ECE) remains strategically important to national technological capability and workforce development in the Philippines, yet student interest in the field is often weak and insufficiently structured. Although educational robotics has been widely associated with positive STEM-related outcomes, fewer studies have examined robotics as a discipline-specific advocacy strategy, and even fewer have translated student-valued robotics attributes into a structured framework for promoting a specific engineering discipline. Addressing this gap, this study developed a Robotics-Based Advocacy Framework for Electronics Engineering using an integrated KANO Model, Importance Performance Analysis (IPA), Quality Function Deployment (QFD) approach within a multiphase mixed-method framework development design. In Phase 1, 25 robotics learning attributes were analyzed. KANO results identified three Attractive attributes, hands-on robot building, sensor integration, and confidence-building tasks, while Better–Worse analysis showed the highest satisfaction gains for affordable robotics kits (56.19%), sensor integration (55.56%), and hands-on robot building (55.14%), with the strongest dissatisfaction risk found in clear learning modules and tutorials (-23.36%). IPA showed that 14 attributes were located in Quadrant I, while only community-centered robotics (F22) fell in Quadrant II, marking it as the primary enhancement area. QFD ranked Experiential Robotics Ecosystem first (64.5422; 22.32%), followed by Structured Curriculum Framework (54.9790; 19.02%), Faculty Development (31.5294; 10.91%), and Mentorship and Industry Linkages (30.0270; 10.39%). In Phase 2, pilot results showed positive mean gains across five domains, with the overall mean increasing from 3.02 to 3.44. The study produced a theory-informed, learner-centered, and data-driven advocacy framework, with pilot findings providing preliminary support for its practical relevance.

Keywords electronics engineering; robotics-based advocacy; educational robotics; industry 4.0; importance performance analysis

1. Introduction

Electronics Engineering (ECE) remains a strategically important discipline because it underpins the design, integration, and operation of technologies central to contemporary life, including embedded systems, telecommunications, automation, control systems, intelligent devices, and robotics. In industrial environments increasingly shaped by digitalization, cyber-physical systems, smart manufacturing, and interconnected infrastructures, ECE plays a vital role in technological innovation, industrial competitiveness, and workforce development. In the Philippine context, the national importance of ECE is reinforced by its formal professional recognition under Republic Act No. 9292 and by the curricular standards governing the Bachelor of Science in Electronics Engineering under CHED CMO No. 101, s. 2017 [1], [2]. These policy instruments affirm that ECE is not merely a specialized academic program, but a field closely tied to national technological capability and the

development of future-ready human resources. The urgency of strengthening the ECE pipeline has become even more pronounced as the Philippine electronics and semiconductor sectors continue to expand. National industry planning has projected the need for a substantially larger technical workforce to support anticipated growth in semiconductor and electronics production, including a target of 128,000 engineers and technicians by 2028 [3]. At the same time, licensure data indicate that ECE remains an active and nationally distributed professional pathway despite its substantial academic demands [4]. These developments suggest that institutions must do more than sustain the availability of ECE programs; they must also improve how the discipline is introduced, framed, and made meaningful to prospective learners, particularly at the stage when students begin forming academic interests and possible career directions.

A persistent challenge is that engineering is often perceived by students as mathematically difficult, highly technical, and disconnected from everyday experience. This issue is especially significant in ECE because many of its core concepts, such as circuits, sensing, control, signal processing, and embedded systems are not readily visible or easily understood without exposure to authentic engineering tasks. When students encounter ECE primarily through abstract descriptions, formulas, or decontextualized instruction, they may fail to appreciate its practical value, creative dimension, and societal relevance. General awareness of the discipline may therefore be insufficient to stimulate genuine interest. What is needed is an advocacy approach that makes ECE concrete, interactive, and personal meaningful. Robotics offers a promising response to this challenge. Educational robotics has been associated with improved engagement, stronger STEM attitudes, greater familiarity with technical concepts, and richer opportunities for applied problem solving because it enables learners to build, test, observe, and refine visible systems [5], [6], [7], [8], [9].

As a learning environment, robotics allows students to encounter programming, sensing, design, and system integration in ways that are hands-on and experientially grounded [7], [10], [11], [12]. This is particularly relevant to ECE because robotics integrates many of the discipline's core domains within a single platform. Through robotics activities, learners can experience engineering not as a distant body of theoretical knowledge, but as an applied, inventive, and purposeful process. In this sense, robotics can function not only as an instructional tool, but also as an advocacy mechanism that helps make ECE more understandable, accessible, and attractive to future learners [13], [14], [15], [16], [17]. The educational value of robotics is well supported in recent literature. Meta-analytic and systematic review studies have shown that robotics-based learning can positively influence STEM-related outcomes, including engagement, competence development, technical familiarity, and higher-order thinking skills [5], [6], [7], [8], [12]. Additional studies suggest that robotics can support communication, collaboration, creativity, critical thinking, and persistence, particularly when implemented through project-based, inquiry-based, and design-centered approaches [11], [14], [17]. Recent work has also shown that robotics experiences can strengthen self-confidence, self-efficacy, and attitudes toward STEM learning [13], [15], [16], [18]. These outcomes are especially relevant to ECE advocacy because students are more likely to consider entering a field when they perceive it as both attainable and worthwhile. The advocacy potential of robotics may be better understood through three complementary theoretical foundations: Expectancy–Value Theory (EVT), Social Cognitive Career Theory (SCCT), and Constructionism. EVT explains that students are more likely to engage in a domain when they believe they can succeed in it and when they perceive the related tasks as useful, important, or interesting [19], [20].

Recent studies continue to show that motivation, value perception, and self-beliefs are strongly associated with academic engagement and future aspirations [21], [22], [23], [24]. In the context of ECE advocacy, EVT suggests that robotics activities may stimulate interest in discipline when they enable learners to experience achievable successes and reveal the practical and socially meaningful

relevance of engineering. SCCT complements this perspective by emphasizing that academic and career interests develop through the interaction of self-efficacy, outcome expectations, goals, and contextual supports [25]. More recent studies have applied SCCT to explain how students form STEM interests and how learning environments shape career orientation [26], [27], [28]. This perspective is especially relevant to ECE because student attraction to the field depends not only on whether they enjoy robotics activities, but also on whether those experiences strengthen confidence, clarify future pathways, and occur within supportive contexts that include mentorship, encouragement, and visible career linkages. Robotics becomes a stronger advocacy tool when it helps students imagine themselves as capable of participating in ECE-related learning and future careers. Constructionism provides the pedagogical basis for why robotics is particularly suitable as an advocacy medium. From a constructionist perspective, learning deepens when students actively create, manipulate, and reflect on meaningful artifacts [29]. Robotics aligns strongly with this view because it transforms abstract engineering concepts into tangible systems that learners can assemble, troubleshoot, and improve.

Recent literature continues to support the value of active, artifact-based, and design-oriented robotics environments in strengthening technical understanding and motivation [7], [9], [10], [12], [30]. In the context of ECE advocacy, this suggests that robotics can serve as more than a motivational add-on; it can function as a meaningful bridge between student curiosity and engineering identity formation. Despite the growing literature on educational robotics, an important gap remains. Much of the existing research has focused on broad outcomes such as STEM engagement, computational thinking, collaboration, technical skill development, and general academic performance [5], [6], [7], [8], [9], [11], [12], [14]. While these contributions are valuable, fewer studies have examined robotics as a deliberate advocacy strategy for promoting interest in a specific engineering discipline. Even fewer have identified which robotics learning attributes students value most, determined which of these attributes require priority institutional attention, and translated such priorities into a structured advocacy framework for program design. As a result, schools and universities that seek to use robotics not only for instruction, but also for discipline-specific advocacy, still have limited evidence on how robotics experiences should be designed to make ECE more understandable, meaningful, and attractive to prospective learners.

This gap is particularly significant in the Philippine setting, where institutions must respond simultaneously to industry demand, policy expectations, and the continuing challenge of attracting students into engineering pathways. If robotics is to be used effectively as an advocacy mechanism, advocacy efforts must move beyond one-time demonstrations, isolated enrichment activities, or intuition-based program design. Instead, they should be grounded in student voice, informed by theory, and translated into concrete institutional actions. A systematic framework-development approach is therefore needed to identify learner-valued robotics attributes, determine which of them require priority attention, and convert those priorities into actionable design requirements for ECE advocacy. To address this need, the present study adopted an integrated KANO, Importance Performance Analysis (IPA)–Quality Function Deployment (QFD) approach. KANO analysis was used to identify and classify student-valued robotics attributes according to the nature of the value they hold for learners [31], [32]. IPA was then used to prioritize these attributes by determining which of them required the greatest institutional attention based on their relative importance and perceived performance [33]. QFD subsequently translated the prioritized learner needs into institutional design requirements for advocacy planning [34]. The integration of these methods constitutes a key contribution of the study because it moves systematically from student perceptions to priority setting, to program design translation, rather than ending at descriptive evaluation alone [31], [32], [35].

Accordingly, this study sought to develop a Robotics-Based Advocacy Framework for Electronics Engineering by (1) identifying student-valued robotics learning attributes, (2) prioritizing the most

critical advocacy-related factors, (3) translating these into structured institutional design requirements through the integrated KANO –IPA–QFD approach, and (4) synthesizing them into a learner-centered advocacy framework for ECE. Anchored in EVT, SCCT, and Constructionism, the study positions robotics not only as a pedagogical tool but also as a theory-informed, learner-centered, and data-driven advocacy mechanism for strengthening awareness of, confidence in, and interest toward Electronics Engineering in the context of Industry 4.0.

2. Material and methods

2.1 Research design

This study adopted a sequential mixed-method framework development design to develop a Robotics-Based Advocacy Framework for Electronics Engineering. The design was sequential because the outputs of one analytical stage informed the next, and it was framework-oriented because the primary objective was to generate a structured advocacy framework rather than to test a pre-existing intervention model. A mixed-method design was appropriate because the study sought both to quantify learner-valued robotics attributes and to interpret how these could be translated into actionable institutional design requirements [36].

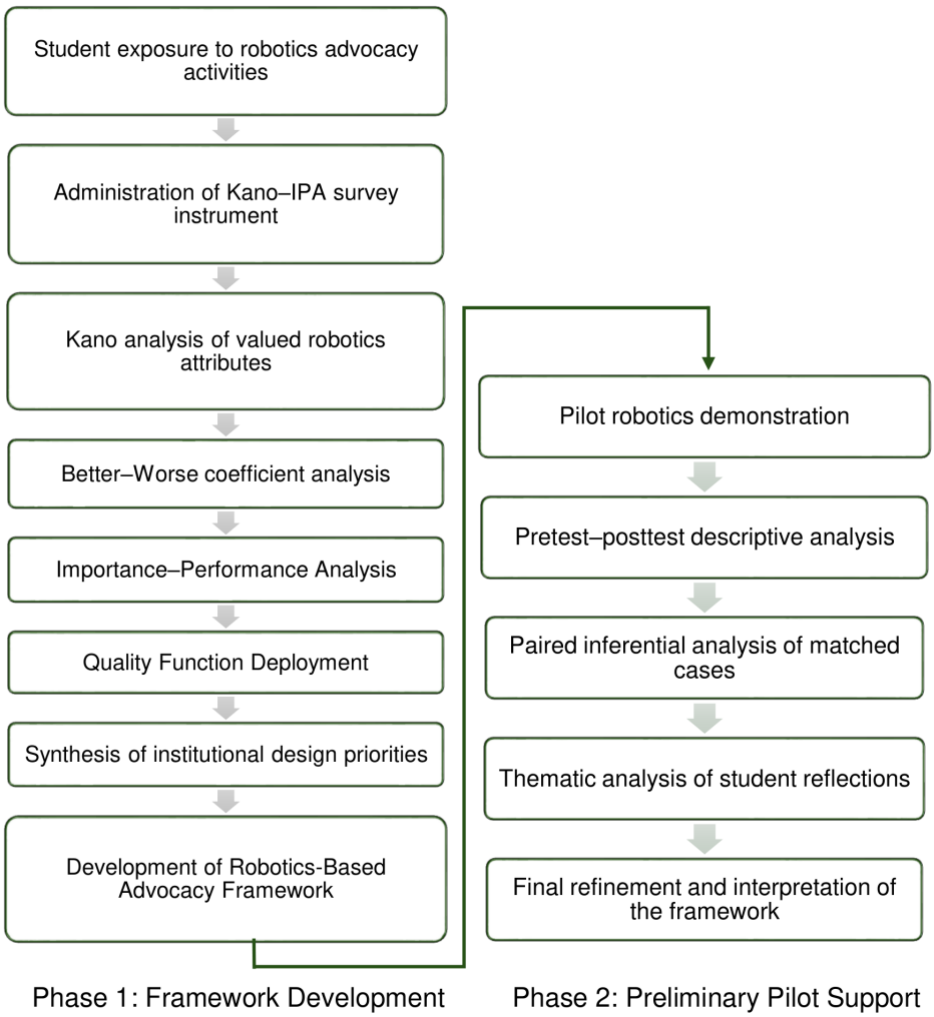

Figure 1. Sequential mixed-method framework development process for the robotics-based advocacy framework for electronics engineering

The study was organized into two related but unequal phases, as shown in Figure 1. Phase 1 served as the primary component of the study and focused on framework development through the integrated use of the Kano Model, Importance–Performance Analysis (IPA), and Quality Function Deployment (QFD). Kano analysis was used to identify and classify the nature of student-valued robotics attributes [29]. IPA was then applied to determine which of these attributes required priority institutional attention based on their relative importance and perceived performance [33]. QFD subsequently translated the prioritized learner needs into institutional design requirements for advocacy planning [34]. Through this sequence, the study moved systematically from learner perceptions to prioritized design elements and, ultimately, to the development of the Robotics-Based Advocacy Framework. Phase 2 functioned as a supplementary component and focused on obtaining preliminary pilot support for the framework's practical relevance through a robotics demonstration. This phase examined whether the advocacy directions derived from Phase 1 were accompanied by observable short-term changes in student awareness, perception, self-efficacy, perceived value, and career interest related to Electronics Engineering. Quantitative evidence was obtained through descriptive pretest-posttest comparison and paired analysis of matched cases, while qualitative evidence was derived from thematic analysis of student reflections [35]. This phase was not intended to serve as a full intervention-effectiveness test or formal framework validation; rather, it was included only to provide initial implementation-based support for the practical relevance of the framework.

The study as shown in Figure 1 moves systematically from student voice to prioritized advocacy needs, to institutional design requirements, and finally to preliminary pilot-based support. In this way, the methodological structure primarily supported the development of the framework, while the pilot component served only to examine its initial practical relevance rather than to function as an equal or confirmatory phase.

2.2 Theoretical foundations of the framework

The proposed framework was conceptually anchored in Expectancy–Value Theory (EVT), Social Cognitive Career Theory (SCCT), and Constructionism. These theories were not treated as variables for direct hypothesis testing in the present study. Rather, they served as complementary interpretive lenses that informed the design of the instrument, guided the interpretation of the findings, and supported the organization of the final Robotics-Based Advocacy Framework. Their combined use provided a stronger conceptual basis for explaining how robotics-based learning experiences may influence student awareness of, confidence in, and interest toward Electronics Engineering (ECE) [19], [20], [25], [29]. EVT provided the motivational foundation of the framework. According to EVT, students are more likely to engage in learning tasks when they believe they can succeed and when they perceive those tasks as useful, important, or enjoyable [19], [20]. Recent studies continue to affirm the importance of competence beliefs, task value, and situational motivation in shaping student engagement, achievement, and future aspirations [21], [22], [23], [24]. In the context of the present study, EVT suggests that robotics-based advocacy becomes more effective when learners experience robotics tasks as achievable and meaningful. When students are able to perform hands-on technical activities successfully and recognize their relevance to real-world applications, they may begin to view ECE not only as a difficult technical field but also as a worthwhile and attainable pathway [9], [15], [24].

SCCT provided the career-development lens of the framework. SCCT explains that academic and career interests develop through the interaction of self-efficacy, outcome expectations, goals, and contextual support [25]. More recent work has continued to demonstrate the relevance of SCCT in explaining how STEM-related experiences shape career interests, especially when students are exposed to supportive environments and authentic learning activities [26], [27], [28]. Within the present

framework, mentorship, teacher guidance, supportive learning conditions, and visible career pathways were treated as essential advocacy elements because they help students connect present robotics experiences with future educational and professional possibilities in ECE. From this perspective, robotics advocacy is not only about making engineering interesting; it is also about helping students interpret their experiences in ways that strengthen confidence, clarify outcomes, and encourage future-oriented engagement with the discipline [15], [27], [28].

Constructionism provided the pedagogical rationale for using robotics as the central advocacy medium. From a constructionist viewpoint, learning becomes deeper and more meaningful when students actively build, manipulate, and reflect on tangible artifacts [29]. Robotics strongly aligns with this view because it allows learners to engage with visible systems that embody abstract principles in electronics, control, programming, and design. Recent studies on educational robotics continue to highlight the value of active, artifact-based, and design-oriented learning environments in strengthening technical understanding, motivation, and learner participation [5], [6], [7], [10], [12], [37]. In the context of the present study, constructionism helps explain why robotics can function as more than a demonstration tool. It creates a learning environment in which abstract ECE concepts become concrete, interactive, and experientially meaningful, thereby making discipline more accessible to prospective learners [7], [8], [10].

Table 1. Theoretical foundations and their alignment with framework dimensions

Theoretical foundation	Key idea	Relevance to robotics advocacy	Related framework dimension
Expectancy–Value Theory (EVT)	Learners are more likely to engage when they believe they can succeed and perceive value in the task [19], [20].	Robotics can strengthen perceived competence and demonstrate the usefulness, meaning, and attractiveness of ECE-related tasks [9], [21], [22], [23], [24].	Motivational Core
Social Cognitive Career Theory (SCCT)	Career interests develop through self-efficacy, outcome expectations, goals, and contextual supports [25].	Mentorship, guidance, and visible ECE career pathways help students connect robotics experiences with future academic and career possibilities [26], [27], [28].	Purpose Alignment / Support System
Constructionism	Learning deepens through active construction, experimentation, and interaction with meaningful artifacts [31].	Robotics makes abstract electronics concepts tangible, interactive, and experientially meaningful [7], [8], [10], [12].	Experiential Core

EVT, SCCT, and Constructionism strengthened the conceptual coherence of the framework. EVT explains why confidence-building and value-enhancing experiences matter in motivating students toward ECE [19], [20]. SCCT explains why support systems, mentorship, and future-oriented career visibility are necessary for translating technical engagement into career-related interest [25], [26], [27], [28]. Constructionism explains why hands-on robotics emerged as a particularly appropriate medium for advocacy by making abstract engineering concepts tangible and engaging [7], [10], [29]. Their integration therefore provided a strong theoretical basis for interpreting the empirical findings and for structuring the major dimensions of the Robotics-Based Advocacy Framework.

2.3 Participants and research context

The participants were 124 senior high school students from partner secondary schools in Cagayan de Oro City. Respondents were selected through purposive sampling based on their participation in robotics-oriented advocacy activities designed to introduce concepts related to Electronics Engineering. This sampling approach was appropriate because the study specifically sought to gather the perceptions of learners who represented the intended audience of future ECE advocacy efforts. The respondents were considered suitable participants because they were at a stage of academic and career exploration in which awareness of degree options, perceived relevance of disciplines, and emerging interests could still be shaped. Their exposure to robotics activities provided an immediate experiential basis for evaluating which attributes of robotics-based learning they found meaningful, motivating, and relevant to Electronics Engineering. The research context consisted of structured robotics-based advocacy sessions that introduced selected concepts related to electronics, programming, control, sensing, and technological problem solving. These sessions were not treated as the primary object of intervention testing. Instead, they served as the common experiential basis from which participants could form and report their perceptions of robotics as a possible entry point to ECE. The resulting framework was therefore grounded in actual exposure rather than hypothetical assumptions about what students might value.

2.4 Instrument development

Data was collected using two researcher-developed instruments designed to support the two phases of the study. The first instrument, the Kano-Based Robotics Advocacy Instrument, was developed for the primary framework-development phase. The second, the Pilot Demonstration Pretest–Posttest Questionnaire, was developed for the supplementary pilot phase. Both instruments were constructed in alignment with the theoretical foundations of the study, Expectancy–Value Theory, Social Cognitive Career Theory, and Constructionism, and with the analytical requirements of the integrated KANO–IPA–QFD approach. The KANO-Based Robotics Advocacy Instrument was designed to capture student perceptions of robotics learning attributes relevant to Electronics Engineering (ECE) advocacy. Item generation was informed by the study's theoretical foundations, the educational robotics literature, and the intended advocacy dimensions of engagement, confidence, instructional support, enjoyment, real-world relevance, and career connection. This process resulted in 25 robotics learning attributes, including hands-on robot building, electronics wiring, microcontroller programming, sensor integration, troubleshooting support, teamwork, creative robot design, Industry 4.0 alignment, ECE connection, mentorship, teacher competency, affordability of kits, simulation tools, clear modules, adequate time, confidence-building tasks, and project showcasing. These attributes were selected because they represented both the motivational and structural conditions through which robotics could function as an advocacy mechanism for ECE.

The final KANO instrument consisted of four parts: (1) respondent profile items, (2) paired functional and dysfunctional Kano items for the 25 robotics features, (3) importance and performance rating scales for each feature, and (4) open-ended response sections, where applicable. The paired Kano items were used to classify the type of value associated with each feature, while the importance and performance sections supported the subsequent IPA. The prioritized attributes derived from Kano and IPA then served as the customer requirements, or "WHATs," for the QFD stage. A second instrument was developed for the pilot implementation phase to assess possible short-term changes following participation in the robotics demonstration.

The Pilot Demonstration Pretest–Posttest Questionnaire was guided by the advocacy objectives of the study and by the motivational and career-related constructs emphasized in the theoretical framework.

Five domains were identified as indicators of preliminary advocacy effect: (1) Awareness of Electronics Engineering, (2) Robotics Learning Perception, (3) Self-Efficacy, (4) Perceived Value of Robotics Learning, and (5) Career Interest in Electronics Engineering. Items were written using a Likert-type format appropriate for pretest and posttest administration, and the posttest version also included open-ended reflection prompts on what students found most interesting and what they learned from the activity. Prior to validation, the questionnaire was reviewed by the researcher to improve clarity, conciseness, and age-appropriateness for senior high school respondents.

Before actual administration, both instruments underwent content validation through expert review using the Content Validity Index (CVI). The validation process examined the relevance, clarity, age-appropriateness, and alignment of each item with the study objectives and intended constructs. The instruments were evaluated by five expert validators with relevant backgrounds in research, education, robotics, engineering, and instrument development. Each item was rated on a 4-point scale ranging from 1 = not relevant to 4 = highly relevant. Item-level content validity was computed using the Item-Level Content Validity Index (I-CVI), while overall scale validity was determined using the Scale-Level Content Validity Index (S-CVI/Ave). For the KANO-Based Robotics Advocacy Instrument, Items 1–4 obtained an I-CVI of 0.80, while Items 5–35 obtained an I-CVI of 1.00. The instrument achieved an S-CVI/Ave of 0.98, indicating excellent content validity. For the Pilot Demonstration Pretest–Posttest Questionnaire, Items 1–5 obtained an I-CVI of 0.80, while Items 6–24 obtained an I-CVI of 1.00, with an overall S-CVI/Ave of 0.96, likewise indicating excellent content validity. Since all items met acceptable retention criteria, all were retained. Minor revisions were nevertheless incorporated based on validator comments, particularly with respect to wording clarity, simplicity of expression, consistency of phrasing, and suitability for senior high school respondents. The finalized versions of both instruments were then used in Phase 1 and Phase 2 of the study.

2.5 Data collection procedure

Data gathering was conducted in coordination with partner secondary schools that participated in the robotics advocacy activity. Prior to the conduct of the study, the necessary permissions were secured by school authorities. Participants were informed of the purpose of the study, and the instrument was administered in a supervised setting to ensure orderly completion. The process began with the conduct of robotics-based advocacy sessions designed to expose students to selected ECE-related concepts through hands-on and observable learning experiences. These sessions allowed students to encounter robotics not merely as a topic of discussion, but as an interactive environment involving building, programming, sensing, debugging, and collaborative problem solving. After completing the advocacy sessions, the participants answered the survey instrument. Instructions were explained before administration so that respondents could properly answer the paired Kano items as well as the importance and performance ratings. Completed questionnaires were checked for completeness before encoding and analysis. In addition to the quantitative survey responses, qualitative observations and participant comments noted during the sessions were considered during framework synthesis to support interpretation of the findings.

2.6 KANO analysis

KANO analysis was used as the first analytical stage of framework development to determine the nature of student-valued robotics learning attributes and to clarify how these attributes contributed to the advocacy potential of robotics for Electronics Engineering (ECE). The method was appropriate because the study did not aim merely to identify whether students liked particular robotics features, but to determine the qualitative structure of those preferences from the learner's perspective [31]. In this study, each robotics attribute was represented through a pair of items: a functional item, which

described the presence of the attribute, and a dysfunctional item, which described its absence. Respondents paired answers were then interpreted using the standard Kano evaluation matrix, which allows each attribute to be classified according to the type of value or satisfaction effect it generates [31].

Based on this procedure, each robotics learning attribute was categorized as Must-Be, One-Dimensional, Attractive, Indifferent, Reverse, or Questionable [31]. These categories provided a more nuanced understanding of student perceptions than a simple preference rating alone. Must-Be attributes represented basic expectations that students assumed should already be present; their absence could generate dissatisfaction even if their presence did not necessarily produce high enthusiasm. One-Dimensional attributes reflected features for which better performance tended to correspond with higher satisfaction. Attractive attributes represented features that were not always expected by students but could substantially enhance the appeal of robotics-based advocacy when present. By contrast, Indifferent attributes reflected elements that had little effect on student response, Reverse attributes suggested features that some students might prefer not to have, and Questionable results indicated inconsistent or unclear response patterns requiring cautious interpretation [31].

KANO analysis was particularly useful in the present study because it enabled the framework to be grounded not only in learner preference, but in the type of value each robotics attribute carried in shaping advocacy appeal. This was important because robotics-based advocacy for ECE involves more than identifying enjoyable activities; it requires understanding which features function as essential conditions, which enhance engagement, and which provide added motivational appeal. In this way, Kano analysis provided the initial evidence base for distinguishing between baseline instructional expectations and high-impact advocacy features. The resulting classifications then served as the foundation for the next analytical stage, where the retained attributes were subjected to IPA for further prioritization [31], [33]. Following the KANO classification stage, IPA was conducted to determine which robotics learning attributes required the greatest strategic attention in the development of the Robotics-Based Advocacy Framework for Electronics Engineering. Whereas Kano analysis clarified the qualitative nature of student-valued attributes, IPA was used to identify which of these attributes should be sustained, strengthened, or prioritized in framework design [33].

In the present study, importance was represented by the better coefficient derived from the Kano analysis, while performance was represented by the mean feature-present rating for each robotics learning attribute. This operationalization was adopted because the better coefficient provided an empirically grounded estimate of the extent to which the presence of a given attribute could enhance student satisfaction and advocacy appeal. In the context of robotics-based advocacy, this was considered a more strategically relevant indicator of importance than a simple direct importance rating, particularly because many attributes that appeared formally Indifferent in dominant Kano classification still showed meaningful satisfaction-enhancing potential when examined through their better coefficients. For each attribute, the importance and performance values were plotted on a two-dimensional IPA matrix using the grand mean of importance and the grand mean of performance as the crosshair values. This produced the four standard interpretive quadrants: Keep Up the Good Work, Concentrate Here, Low Priority, and Possible Overkill [33]. Attributes located in Keep Up Good Work were interpreted as important and well delivered, indicating features that should be preserved and reinforced. Attributes in Concentrate Here were treated as the most urgent priorities because they combined high importance with relatively lower performance. Attributes in Low Priority were considered less urgent for immediate framework emphasis, while those in Possible Overkill reflected features receiving comparatively greater attention than warranted by their relative strategic importance [33]. This IPA procedure strengthened the framework-development process by moving the analysis from classification to prioritization. While Kano analysis identified the nature of the value associated

with each robotics attribute, IPA clarified which of those attributes required the strongest institutional response. In this way, IPA provided the decision-oriented basis for determining which learner-valued robotics attributes should be maintained, improved, or strategically emphasized before their translation into structured institutional design requirements through Quality Function Deployment (QFD) [33], [34].

2.7 QFD

QFD was used in the third analytical stage to translate prioritized learner needs into strategic program design requirements for robotics-based advocacy in Electronics Engineering (ECE). In this study, the robotics learning attributes that had been identified through Kano analysis and subsequently prioritized through Importance–Performance Analysis (IPA) were treated as the customer requirements, or the "WHATs," of the framework [34]. These represented the specific features of robotics learning that students perceived as valuable and that required institutional attention. The next step was to determine how these learner-valued needs could be addressed through concrete institutional responses. These responses functioned as the design requirements, or the "HOWs," of the framework [34].

To operate this process, a House of Quality structure was used to map the relationships between the prioritized learner needs and the proposed institutional design responses [34]. Within this matrix, relationship strengths were assigned to indicate the extent to which a given design requirement could address a particular student-valued attribute. Through this mapping procedure, weighted priorities were generated, allowing the study to determine which strategic actions carried the greatest potential for improving the advocacy effectiveness of robotics-based learning. This step was important because it moved the analysis beyond identifying what students valued and what required improvement, toward specifying which institutional responses should receive the strongest emphasis in framework design [34]. The QFD stage served as the principal translational mechanism of the study. Rather than ending with a descriptive account of student preferences, the analysis converted learner perceptions into actionable planning components for advocacy. In practical terms, this meant identifying which program design responses were most strongly aligned with the prioritized robotics attributes valued by students.

These responses included strengthening experiential robotics activities, improving instructional organization and sequencing, enhancing teacher and mentorship support, increasing the visibility of ECE-related pathways, and reinforcing the real-world and career relevance of robotics experiences. In this way, QFD enabled the study to move from learner voice to institutional strategy, thereby providing the direct design basis for the final Robotics-Based Advocacy Framework [34]. The QFD stage completed the progression from classification (KANO) to prioritization (IPA), to translation into strategic design requirements (QFD). This strengthened the methodological coherence of the study by ensuring that the final framework was not based on intuition alone, but on a systematic conversion of student-valued robotics attributes into structured advocacy directions for institutional application [31], [33], [34].

2.8 Data analysis

Data analysis was carried out through a multistage procedure that combined framework-development analysis with preliminary implementation analysis. The first three analytical stages were used to construct the Robotics-Based Advocacy Framework from student-valued robotics attributes, while the succeeding analyses were used to examine the outcomes of the pilot implementation. In this way, the study moved from identifying and prioritizing learner-valued attributes to generating initial empirical evidence regarding the advocacy relevance of the proposed framework. Overall, the analytical process

consisted of Kano analysis, IPA, QFD, descriptive pretest–posttest analysis, paired inferential analysis, and descriptive thematic content analysis [31], [33], [34], [35].

The first stage of analysis involved the Kano model, which was used to determine the nature of student-valued robotics learning attributes. For each robotics learning attribute, respondents answered a functional question describing the presence of the attribute and a dysfunctional question describing its absence. The paired responses were interpreted using the standard Kano evaluation matrix, which allowed each attribute to be classified as Must-Be, One-Dimensional, Attractive, Indifferent, Reverse, or Questionable [31]. This stage was important because the study did not aim merely to identify which robotics features students liked, but to clarify the type of value each feature carried from the learner's perspective. Must-Be attributes represented basic expectations that should already be present, One-Dimensional attributes reflected features for which better performance corresponded to greater satisfaction, and Attractive attributes represented features that could substantially enhance the appeal of robotics-based advocacy when present [31]. To enrich the interpretation, Better and Worse coefficients were also computed to estimate the extent to which the presence of an attribute increased satisfaction and the absence of an attribute generated dissatisfaction. This coefficient analysis was especially useful when absolute category assignment alone did not fully distinguish the relative advocacy value of certain attributes [31]. Thus, Kano analysis provided the initial evidence base for identifying which robotics learning features functioned as expected conditions, performance drivers, or high-impact motivational enhancers.

The second stage involved IPA. In this study, the better coefficient derived from the Kano stage was used as the operational indicator of importance, while the mean functional rating for each attribute was used as the indicator of performance. The mean importance and mean performance values across all attributes served as the IPA crosshairs, and each attribute was plotted into one of four quadrants: Keep Up the Good Work, Concentrate Here, Low Priority, or Possible Overkill [33]. This stage enabled the study to move beyond the qualitative classification of value and identify which robotics learning attributes required the greatest institutional attention. Attributes in the Concentrate Here quadrant were treated as the most critical because they combined relatively high importance with lower performance. Attributes in Keep Up the Good Work indicated strengths that should be maintained, those in Low Priority reflected less urgent concerns, and those in Possible Overkill suggested features receiving relatively greater attention than warranted by their strategic importance [33]. In this way, IPA served as the prioritization stage of the framework-development process by distinguishing between generally desirable features and strategically urgent advocacy needs.

The third stage involved Quality Function Deployment (QFD). In the House of Quality matrix, the 25 student-valued robotics attributes identified and prioritized through the preceding stages served as the customer requirements, or the "WHATs," while eight proposed institutional design responses served as the "HOWs" [34]. These institutional design requirements included community integration, mentorship and industry linkages, structured curriculum framework, faculty development, resource sustainability system, career pathway integration, experiential robotics ecosystem, and showcase platform. Relationship weights were assigned between the WHATs and HOWs using the standard 1–3–9 weighting logic to represent weak, moderate, and strong relationships [34]. Weighted totals were then computed to generate the priority ranking of the institutional design requirements. This stage translated learner perceptions into actionable planning components by identifying which institutional responses most strongly addressed the prioritized student-valued robotics attributes. The QFD outputs therefore provided the direct basis for synthesizing the Robotics-Based Advocacy Framework [34]. The Kano–IPA–QFD sequence enabled the study to move from classification, to prioritization, to strategic design translation. In addition to these framework-development stages, the study also included a pilot

implementation in the form of a robotics demonstration administered to participating senior high school students.

The pilot implementation was designed as an introductory advocacy intervention rather than a full robotics curriculum. Its purpose was to provide direct, experience-based exposure to selected robotics and electronics concepts in order to examine whether such exposure was accompanied by short-term changes in awareness, learning perception, self-efficacy, perceived value, and interest in Electronics Engineering. The demonstration included practical learning experiences related to coding or programming, wiring, circuit connection, and hands-on or simulation-based robotics tasks, with emphasis on direct participation, guided manipulation, and observable outputs. The pilot followed a pretest–posttest procedure, in which the pretest was administered before the robotics demonstration and the posttest was administered immediately after the activity. The posttest also included open-ended reflection items asking students what they found most interesting and what new concepts they learned. These reflection responses were used to support the interpretation of the quantitative findings.

For the pilot implementation analysis, several forms of analysis were conducted. First, descriptive statistics were used to summarize respondent profile data, including age, sex, grade level, academic track, and prior robotics participation. For the descriptive pretest–posttest analysis, means, standard deviations, and mean gains were computed at both the domain level and the item level to summarize changes between the two administrations. This stage provided an initial descriptive view of whether student responses showed positive movement after exposure to the robotics demonstration. Second, a paired inferential analysis was conducted using only the final matched subset of respondents. The normality of the difference scores was first examined. When the assumption of approximate normality was met, the paired-samples t-test was used; when normality was not met, the Wilcoxon signed-rank test was used as the nonparametric alternative. Effect sizes were also computed to assess the magnitude of the observed changes. Third, the open-ended posttest reflection responses were analyzed using descriptive thematic content analysis [35]. Recurring ideas were grouped into broader themes such as coding or programming, wiring and circuit connection, hands-on or simulation-based activity, and electronics and robotics concepts. These themes were then used to explain and contextualize the quantitative results and to clarify how students experienced the pilot advocacy intervention.

This study addressed both the framework-development objective and the supplementary pilot objective. The KANO–IPA–QFD stages generated the primary evidence base for constructing the Robotics-Based Advocacy Framework, while the descriptive, inferential, and thematic analyses from the pilot phase provided preliminary support for the practical relevance of the proposed framework. In this way, the study moved from student-valued robotics attributes to institutional design priorities, and finally to initial implementation-based evidence that informed the interpretation of the framework's potential educational relevance for Electronics Engineering advocacy [31], [33], [34], [35].

2.9 Ethical considerations

The study observed appropriate ethical procedures in the conduct of research involving senior high school students. Prior to data gathering, coordination was undertaken with partner schools to secure the necessary institutional authorization for the conduct of the robotics advocacy activity and the administration of the research instruments. Participants were informed of the purpose of the study, and participation was voluntary. Respondents were also informed that their answers would be used for academic and research purposes. To protect participant privacy, no personally identifying information was reported in the presentation, analysis, or interpretation of the findings. All results were presented only in aggregated, summarized, or anonymized form. Reflection responses were likewise treated

confidentially and were reported only in summarized or anonymized form to prevent the identification of individual participants.

For the pilot pretest–posttest analysis, a respondent coding procedure was used to support the matching of responses across the two measurement points. Respondent codes served as the primary identifier, while age, sex, and grade level were used only as secondary verification variables. These supporting variables were handled carefully and solely for analytical matching purposes. When records contained incomplete or inconsistent identifiers, matching decisions were classified conservatively, and only the final defensible matched subset was retained for within-subject inferential analysis. This procedure helped preserve both analytic rigor and participant confidentiality. All questionnaires were collected, checked for completeness, encoded, and analyzed solely for the purpose of developing and examining the Robotics-Based Advocacy Framework for Electronics Engineering. Because the study involved secondary school students, particular care was taken in the handling, encoding, and reporting of data to ensure responsible treatment of participant responses and protection of confidentiality throughout the research process.

3. Results and discussion

The development of the framework as in Figure 1 began with student exposure to robotics-based advocacy activities, followed by the collection of perception data regarding learner-valued robotics attributes. These data were analyzed through a sequential process consisting of Kano analysis, better–worse coefficient analysis, IPA, and QFD. Through this progression, student-valued attributes were first identified and interpreted in terms of their satisfaction structure, then prioritized according to their relative importance and performance, and finally translated into strategic institutional design requirements. The resulting priorities were synthesized into the proposed Robotics-Based Advocacy Framework for Electronics Engineering. To provide preliminary implementation evidence, the framework was further examined through a pilot robotics demonstration, which was evaluated using respondent profile analysis, descriptive pretest–posttest results, paired inferential statistics, and thematic analysis of student reflection responses. These analyses allowed the study to present both the empirical basis of the framework and its initial practical relevance as an advocacy mechanism for strengthening student awareness of, confidence in, and interest toward Electronics Engineering.

3.1 KANO findings: Student-valued robotics learning attributes

The Kano analysis was conducted across 25 robotics learning attributes (F10–F34) using paired functional and dysfunctional questions. Based on dominant category frequencies, only three attributes were classified as Attractive (Excitement) under absolute Kano categorization: hands-on robot building and assembly (F10), sensor integration activities (F13), and confidence-building robotics tasks (F33). The remaining attributes were classified as No Difference in absolute terms. While this pattern may initially suggest that most attributes do not substantially influence student satisfaction, the better–Worse coefficient analysis revealed a more nuanced interpretation. In educational contexts, absolute Kano categories often underrepresent the strategic value of attributes because students do not necessarily enter robotics activities with rigid baseline expectations. For this reason, the Better and Worse coefficients provide a more meaningful basis for identifying design priorities [7], [14]. Table 2 presents the Kano classification and Better–Worse coefficients of the robotics learning attributes.

Table 2. Kano classification and Better–Worse coefficients of robotics learning attributes

Code	Robotics learning attribute	KANO category	Better coefficient	Worse coefficient
F10	Hands-on robot building and assembly	Excitement	55.14%	-12.15%
F11	Hands-on electronics wiring and circuit building	No Difference	47.12%	-14.42%
F12	Microcontroller programming for robot control	No Difference	44.95%	-16.51%
F13	Sensor integration activities	Excitement	55.56%	-13.89%
F14	Actuator and motor control activities	No Difference	43.64%	-11.82%
F15	Step-by-step scaffolding during robotics tasks	No Difference	43.81%	-12.38%
F16	Troubleshooting and debugging support	No Difference	36.70%	-17.43%
F17	Project-based robotics challenges	No Difference	38.74%	-11.71%
F18	Team-based robotics collaboration	No Difference	47.17%	-12.26%
F19	Opportunities to design robots creatively	No Difference	52.34%	-15.89%
F20	Real-world problem-solving using robotics	No Difference	48.57%	-20.00%
F21	Robotics projects related to Industry 4.0 technologies	No Difference	41.41%	-10.10%
F22	Robotics projects solving real community problems	No Difference	47.57%	-13.59%
F23	Connection of robotics activities to Electronics Engineering	No Difference	40.57%	-11.32%
F24	Orientation on ECE specializations	No Difference	36.61%	-11.61%
F25	Career talks from robotics/electronics professionals	No Difference	47.27%	-18.18%
F26	Mentorship from engineers or robotics experts	No Difference	48.62%	-13.76%
F27	Teacher competence in robotics facilitation	No Difference	50.93%	-17.59%
F28	Availability of affordable robotics kits	No Difference	56.19%	-20.95%
F29	Availability of spare parts and maintenance support	No Difference	52.78%	-21.30%
F30	Use of simulation tools when hardware is limited	No Difference	38.89%	-19.44%
F31	Clear learning modules and tutorials	No Difference	51.40%	-23.36%
F32	Adequate time for robotics sessions	No Difference	49.07%	-19.44%
F33	Confidence-building robotics tasks	Excitement	52.78%	-16.67%
F34	Opportunities to showcase robotics projects	No Difference	41.75%	-17.48%

The three Attractive attributes represent the most direct motivational amplifiers within the robotics advocacy environment. Hands-on robot building and assembly (F10) achieved a better coefficient of 55.14%, indicating strong satisfaction gain when present. Sensor integration activities (F13) yielded a slightly higher better coefficient of 55.56%, reflecting the appeal of intelligent and responsive robotics systems. Confidence-building robotics tasks (F33) also emerged as an Attractive feature with a better coefficient of 52.78%, suggesting that students respond positively to tasks that reinforce their sense of competence. These findings indicate that the most persuasive elements of robotics-based advocacy are not merely technical in nature; they are also psychologically enabling. A deeper inspection of the

coefficients shows that several attributes classified as No Difference in absolute terms still carried strong strategic importance. Availability of affordable robotics kits (F28) posted the highest better coefficient in the dataset at 56.19%, exceedingly even the three Attractive attributes. Similarly, availability of spare parts and maintenance support (F29) and clear learning modules and tutorials (F31) recorded better coefficients of 52.78% and 51.40%, respectively. These values indicate that infrastructure and instructional support are strong satisfaction drivers even when they do not emerge as Attractive under absolute Kano categorization.

At the same time, the Worse coefficients showed that several attributes carried substantial dissatisfaction risk when absent. The most negative Worse coefficient was recorded for clear learning modules and tutorials (F31) at -23.36%, followed by availability of spare parts and maintenance support (F29) at -21.30%, availability of affordable robotics kits (F28) at -20.95%, and real-world problem-solving using robotics (F20) at -20.00%. These results indicate that some attributes function less as excitement generators and more as implementation safeguards. Their absence is likely to weaken the overall robotics learning experience and undermine the effectiveness of the advocacy effort. To make these patterns more visible, Table 3 presents the five highest better coefficients and the five most negative Worse coefficients.

Table 3. Highest, better coefficients and strongest worse coefficients

Rank	Highest better coefficients	Better
1	F28 – Availability of affordable robotics kits	56.19%
2	F13 – Sensor integration activities	55.56%
3	F10 – Hands-on robot building and assembly	55.14%
4	F29 – Availability of spare parts and maintenance support	52.78%
5	F33 – Confidence-building robotics tasks	52.78%
Rank	**Strongest worse coefficients**	**Worse**
1	F31 – Clear learning modules and tutorials	-23.36%
2	F29 – Availability of spare parts and maintenance support	-21.30%
3	F28 – Availability of affordable robotics kits	-20.95%
4	F20 – Real-world problem-solving using robotics	-20.00%
5	F30 – Use of simulation tools when hardware is limited	-19.44%

Figure 2. Better–Worse coefficient plot of robotics learning attributes

The KANO findings suggest a two-part structure in student-valued robotics attributes. The first part consists of experiential drivers, such as hands-on building, sensor integration, and confidence-building tasks, which increase satisfaction and engagement. The second part consists of structural stabilizers, such as affordability, spare parts, clear modules, and simulation tools, which protect the quality, accessibility, and continuity of the robotics experience. This distinction is important because it shows that an effective robotics advocacy framework must not rely on excitement alone. It must also secure the enabling conditions that prevent dissatisfaction and support sustained participation.

3.2 IPA findings: Priority advocacy factors

To determine which robotics learning attributes should be maintained, improved, or deprioritized, IPA was conducted using the Better coefficient as the importance measure and the mean functional rating as the performance measure [14]. The overall IPA crosshair values were 0.467832 for importance and 3.964194 for performance. Attributes were then distributed into four quadrants: Keep Up the Good Work (Q1), Concentrate Here (Q2), Low Priority (Q3), and Possible Overkill (Q4). The IPA results showed that the majority of the robotics learning attributes were located in Quadrant I, indicating that they were both highly valued by students and currently perceived as well delivered. This is an important finding because it suggests that the robotics advocacy experience already aligns strongly with student expectations. In practical terms, the robotics environment was not only attractive but also functioning effectively across many of its most important dimensions. Table 5 presents full IPA results and quadrant placement.

Table 4. IPA results and quadrant placement of robotics learning attributes

Code	Importance (Better)	Performance	Quadrant	Interpretation
F10	0.5514	4.0323	Q1	Keep up the good work
F11	0.4712	3.9677	Q1	Keep up the good work
F12	0.4495	3.9597	Q3	Low priority
F13	0.5556	4.1129	Q1	Keep up the good work
F14	0.4364	4.0484	Q4	Possible overkill
F15	0.4381	3.8871	Q3	Low priority
F16	0.3670	3.7661	Q3	Low priority
F17	0.3874	3.9355	Q3	Low priority
F18	0.4717	4.0242	Q1	Keep up the good work
F19	0.5234	4.0887	Q1	Keep up the good work
F20	0.4857	3.9758	Q1	Keep up the good work
F21	0.4141	3.7339	Q3	Low priority
F22	0.4757	3.7581	Q2	Concentrate here
F23	0.4057	3.8710	Q3	Low priority
F24	0.3661	3.8306	Q3	Low priority
F25	0.4727	4.0968	Q1	Keep up the good work
F26	0.4862	4.0403	Q1	Keep up the good work
F27	0.5093	4.0242	Q1	Keep up the good work
F28	0.5619	4.0806	Q1	Keep up the good work
F29	0.5278	4.0887	Q1	Keep up the good work
F30	0.3889	3.8145	Q3	Low priority
F31	0.5140	4.1129	Q1	Keep up the good work
F32	0.4907	4.0000	Q1	Keep up the good work
F33	0.5278	4.1290	Q1	Keep up the good work
F34	0.4175	3.7258	Q3	Low priority

Fourteen attributes were positioned in Quadrant I, confirming that the strongest features of the robotics advocacy environment are already being delivered effectively. These attributes included hands-on robot building (F10), electronics wiring (F11), sensor integration (F13), team collaboration (F18), creative robot design (F19), real-world problem solving (F20), career talks (F25), mentorship (F26), teacher competency (F27), affordable robotics kits (F28), spare parts support (F29), clear learning modules (F31), adequate session time (F32), and confidence-building tasks (F33). These findings show that the advocacy environment is strong not only in its experiential core, but also in structural and support-related dimensions. Only one attribute fell into Quadrant II (Concentrate Here): robotics projects solving real community problems (F22), with an importance value of 0.4757 and a performance mean of 3.7581. This makes F22 the single most important underperforming attribute in the dataset. Its placement is especially significant because it points to unrealized advocacy potential. Students clearly value community-relevant robotics, but current implementation has not fully met their expectations in this area.

Nine attributes were classified under Quadrant III (Low Priority), including microcontroller programming (F12), step-by-step scaffolding (F15), troubleshooting support (F16), project-based challenges (F17), Industry 4.0 project alignment (F21), connection to ECE (F23), orientation on ECE specializations (F24), simulation tools (F30), and showcasing opportunities (F34). These attributes are not necessarily unimportant in absolute terms. Rather, their placement suggests that students do not perceive them as primary drivers of immediate satisfaction or engagement. This supports the interpretation that advocacy should begin with experience-rich engagement and then embed more theoretical or explanatory elements later. Only one attribute, actuator and motor control activities (F14), was in Quadrant IV (Possible Overkill). This means that students perceived it as relatively well delivered but lower in importance compared with other features. The implication is not that motor-control activities should be removed, but that they may not require additional emphasis relative to more influential attributes. To provide a visual summary of the quadrant distribution of the robotics learning attributes, Figure 3 presents the IPA quadrant plot based on the grand mean values of importance and performance.

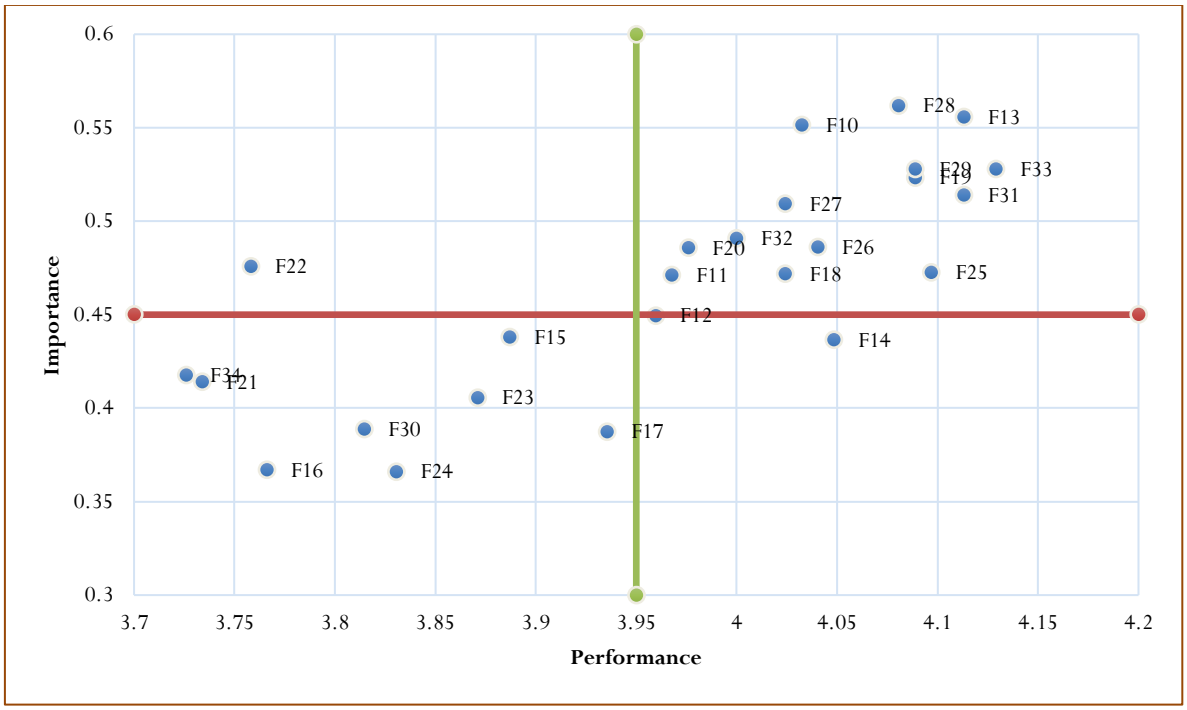

Figure 3. IPA quadrant plot of robotics learning attributes

As shown in Figure 3, the clustering of attributes in Quadrant I indicates that the robotics advocacy environment is already performing strongly across many of the dimensions most valued by students, while F22 stands out as the primary enhancement area requiring focused attention. The IPA findings reinforce three key design implications. First, the experiential features of robotics advocacy are already functioning effectively and should be preserved. Second, community-centered robotics should be treated as the primary enhancement area. Third, theoretical or explanatory features such as ECE orientation and Industry 4.0 alignment appear to be more effective when embedded within experiential learning rather than delivered as standalone components.

3.3 QFD findings: Translation into strategic program design requirements

When the Kano and IPA findings are considered together, a three-tier strategic architecture emerges. The first tier consists of experiential drivers, including hands-on robot building, sensor integration, creative design, and confidence-building tasks. These features either emerged as Attractive attributes or showed strong satisfaction potential and high-performance alignment. They form the motivational core of the robotics advocacy framework. The second tier consists of structural stabilizers, including affordable kits, spare parts, clear modules, adequate time, and teacher competency. These attributes may not have emerged as Attractive under absolute Kano categorization, but the Better–Worse coefficients and IPA positioning show that they are essential to sustaining quality and preventing dissatisfaction. Their absence would likely weaken the overall advocacy environment. The third tier is the strategic expansion area, represented by robotics projects that solve real community problems. The fact that F22 emerged as the only Quadrant II attribute indicates that this feature deserves focused institutional attention in future framework implementation. Table 5 summarizes this integrated interpretation. This synthesis shows that robotics-based advocacy should be built on three interacting principles: motivation, stability, and purpose. Motivation comes from engaging and empowering experiences. Stability comes from instructional and material support. Purpose comes from connecting robotics to community relevance and wider societal value.

Table 5. Integrated Kano–IPA synthesis of robotics advocacy priorities

Strategic tier	Key attributes	Evidence from results	Framework implication
Experiential drivers	F10, F13, F19, F33	Attractive / high Better / Q1	Preserve as motivational core
Structural stabilizers	F27, F28, F29, F31, F32	High Better / strong Worse / Q1	Treat as non-negotiable design safeguards
Strategic expansion area	F22	Q2 Concentrate here	Strengthening community-centered robotics integration

3.4 QFD findings: Translation into strategic program design requirements

While Kano and IPA identified which robotics attributes were valued and where improvement was needed, QFD was used to translate these student-valued attributes into institutional design requirements [14]. In the House of Quality matrix, the 25 robotics learning attributes served as the WHATs, while eight institutional responses served as the HOWs: Community Integration (H1), Mentorship and Industry Linkages (H2), Structured Curriculum Framework (H3), Faculty Development (H4), Resource Sustainability System (H5), Career Pathway Integration (H6), Experiential Robotics Ecosystem (H7), and Showcase Platform (H8). The total weighted score across all eight design requirements was 289.1032. Table 6 presents the resulting priority ranking.

Table 6. QFD results: institutional design requirements and priority ranking

Design requirement	Total score	% Priority	Rank
H7 Experiential Robotics Ecosystem	64.5422	22.32%	1
H3 Structured Curriculum Framework	54.9790	19.02%	2
H4 Faculty Development	31.5294	10.91%	3
H2 Mentorship and Industry Linkages	30.0270	10.39%	4
H1 Community Integration	28.7198	9.93%	5
H6 Career Pathway Integration	28.1560	9.74%	6
H8 Showcase Platform	27.6252	9.56%	7
H5 Resource Sustainability System	23.5246	8.14%	8
Overall Total	289.1032		

The highest-ranked design requirement was Experiential Robotics Ecosystem (H7) at 22.32%, confirming that the central institutional priority should be the deliberate creation of a robotics environment grounded in building, prototyping, interaction, and confidence-building tasks. This is highly consistent with the Kano and IPA findings, where hands-on building, sensor integration, and confidence-building emerged as dominant satisfaction and performance drivers. The second-ranked design requirement was Structured Curriculum Framework (H3) at 19.02%. This confirms that student engagement must be supported by curricular coherence, sequencing, and clear instructional modules. The prominence of curriculum design also reflects the strong dissatisfaction risk associated with the absence of clear learning modules, as shown by the most negative Worse coefficient for F31. The third- and fourth-ranked requirements, Faculty Development (H4) at 10.91% and Mentorship and Industry Linkages (H2) at 10.39%, indicate that human support systems are central to the framework. These findings align with the importance of teacher competency, mentorship, and career talks in the Kano and IPA analyses. In practical terms, the framework requires capable facilitators and visible role models, not just equipment and activities. The middle-ranked requirements, Community Integration (H1) at 9.93% and Career Pathway Integration (H6) at 9.74%, correspond directly to the importance of connecting robotics to social relevance and future professional pathways. This is especially important given the Quadrant II placement of F22, which identified community-centered robotics as the primary improvement area. Finally, Showcase Platform (H8) at 9.56% and Resource Sustainability System (H5) at 8.14% completed the design architecture. Although resource sustainability ranked lowest in the QFD priorities, this should not be interpreted as insignificant. Rather, it suggests that resources function as enabling infrastructure rather than direct motivational drivers. They support the system, but do not independently generate student engagement. Overall, the QFD findings transform student voice into a concrete institutional architecture. The resulting design logic is clear: an effective robotics advocacy framework for Electronics Engineering must be experience-first, curriculum-supported, human-guided, socially relevant, and career-connected.

3.5 Pilot robotics demonstration: Results and initial evidence

To provide initial empirical evidence for the practical relevance of the proposed Robotics-Based Advocacy Framework, a pilot robotics demonstration was conducted among senior high school students. The pilot was designed as an introductory advocacy intervention rather than a full instructional program. Its purpose was to examine whether short-term exposure to robotics activities could positively influence students' awareness of Electronics Engineering (ECE), perceptions of robotics learning, self-efficacy, perceived value of robotics, and career interest in ECE. The results are presented through respondent profile data, descriptive pretest–posttest comparisons, paired inferential findings, posttest reflections, and direct posttest responses regarding interest in learning

more about Electronics Engineering. These findings provide preliminary evidence that robotics can function as a meaningful and motivational entry point for ECE advocacy.

3.5.1 Respondent profile

A total of 41 students completed the pretest, while 38 students completed the posttest. Although the demonstration was administered to the same cohort, the number of usable responses differed slightly because some records were incomplete or inconsistent. Nevertheless, the two groups remained broadly comparable in terms of age, sex, grade level, and academic strand. Most respondents were 17 years old, female, and in Grade 12, and all belonged to the General Academic Strand (GAS). This profile is important because it shows that the pilot reached students who were approaching academic decision-making stages, but who were not necessarily enrolled in a highly technical track.

Table 7. Respondent profile of the pilot robotics demonstration

Variable	Pretest (n = 41)	Post test (n = 38)
Predominant age	17 years old (51.2%)	17 years old (44.7%)
Female	28 (68.3%)	24 (63.2%)
Male	13 (31.7%)	14 (36.8%)
Grade 12	29 (70.7%)	28 (73.7%)
Grade 11	12 (29.3%)	10 (26.3%)
GAS track	41 (100.0%)	38 (100.0%)
Prior robotics participation: Yes	8 (19.5%)	34 (89.5%)
Prior robotics participation: No	33 (80.5%)	2 (5.3%)

The profile shows that the intervention was delivered primarily to students with limited prior robotics exposure, since only 19.5% reported previous robotics participation before the activity. This strengthens the interpretation of the pilot results, because the observed gains are more plausibly associated with a relatively novel and meaningful robotics experience rather than with prior familiarity. From an advocacy standpoint, this is especially relevant: the intervention reached students who were near the point of making future academic choices yet had limited previous access to robotics as a pathway into understanding Electronics Engineering.

3.5.2 Descriptive pretest–posttest results

The descriptive pretest–posttest analysis examined five domains: Awareness of Electronics Engineering, Robotics Learning Perception, Self-Efficacy, Perceived Value of Robotics Learning, and Career Interest in Electronics Engineering. Mean scores, standard deviations, and mean gain values were computed to determine the direction and magnitude of change after participation in the demonstration. The descriptive results provide an overall picture of response shifts before inferential testing of the matched subset.

Table 8. Pretest–posttest mean scores by domain

Domain	Pretest mean	Pretest SD	Posttest mean	Posttest SD	Mean gain
Awareness of ECE	3.13	0.96	3.39	0.97	0.26
Robotics Learning Perception	3.11	1.02	3.58	0.97	0.47
Self-Efficacy	2.93	0.85	3.40	0.93	0.47

Domain	Pretest mean	Pretest SD	Posttest mean	Posttest SD	Mean gain
Perceived Value	3.10	0.89	3.48	0.99	0.38
Career Interest in ECE	2.84	0.84	3.34	0.99	0.50
Overall Mean	3.02	0.82	3.44	0.90	0.42

All five domains showed positive gains from pretest to posttest. The overall mean increased from 3.02 to 3.44, yielding an overall gain of 0.42. The largest domain-level improvement was observed in Career Interest in Electronics Engineering (+0.50), followed by Robotics Learning Perception (+0.47) and Self-Efficacy (+0.47). Perceived Value also improved substantially (+0.38), while Awareness of ECE showed the smallest but still positive gain (+0.26). This pattern suggests that the demonstration was especially effective in enhancing students' motivational and confidence-related responses, while also producing meaningful gains in awareness of the discipline. To examine which specific indicators changed most strongly, item-level means were also reviewed.

Table 9. Selected item-level pretest–posttest gains

Item	Indicator	Pretest Mean	Posttest Mean	Gain
Q15	Belief in successfully completing robotics or automation tasks	2.71	3.45	0.74
Q20	Would consider studying ECE in college	2.63	3.26	0.63
Q14	Capability to learn basic programming used in robotics	3.05	3.61	0.56
Q18	Robotics helps develop problem-solving skills	3.05	3.61	0.56
Q11	Robotics connects science and mathematics to real-world applications	3.02	3.55	0.53
Q9	Robotics activities make learning more interesting and engaging	3.20	3.71	0.52
Q7	Understands careers Electronics Engineers can pursue	2.93	3.42	0.49
Q16	Robotics is useful for understanding future technologies	3.07	3.53	0.45

The strongest gains occurred in indicators related to task confidence, openness to ECE as a college option, programming capability, problem-solving value, real-world relevance, and engagement. In particular, the gain in Q15 (+0.74) indicates that the demonstration substantially improved students' belief that they could successfully complete robotics or automation tasks. Likewise, the increase in Q20 (+0.63) suggests a meaningful rise in students' openness to considering ECE in college. These findings are especially important in an advocacy context because they point to early shifts in perceived capability and academic openness, two conditions that are central to interest formation in technical fields. At the same time, the smallest gains were recorded in more explicitly conceptual or professional-context items, such as awareness that ECE involves robotics, automation, and embedded systems (Q6, +0.06) and recognition that robotics is relevant for Industry 4.0 careers (Q17, +0.12). This suggests that the pilot was more effective as a motivational and experiential exposure activity than as a deep explanatory intervention. Future versions may therefore benefit from stronger mini-lectures or facilitated discussions that more explicitly connect the activity to Electronics Engineering, embedded systems, sensors, actuators, and Industry 4.0 applications.

3.5.3 Paired inferential analysis

To determine whether the observed changes were statistically meaningful at the individual level, paired inferential analysis was conducted using the final matched subset of 18 cases. Matching was based primarily on respondent codes, with age, sex, and grade level used as supporting verification variables. Because minor inconsistencies were observed in some records, only verified and probable matches were retained. This conservative approach allowed the study to assess within-subject change while maintaining reasonable confidence in case matching.

Table 10. Paired inferential results for the matched subset

Domain	n	Pretest Mean	Posttest Mean	Mean Gain	Test Used	Test Statistic	p-value	Effect Size	Decision
Awareness of ECE	18	3.07	3.69	0.61	Wilcoxon	W = 28.50	0.041	r = 0.51	Significant
Robotics Learning Perception	18	3.22	3.87	0.65	Paired t-test	t = 2.21	0.041	d = 0.52	Significant
Self-Efficacy	18	3.08	3.56	0.47	Paired t-test	t = 2.34	0.032	d = 0.55	Significant
Perceived Value	18	3.30	3.67	0.37	Paired t-test	t = 1.72	0.104	d = 0.41	Not Significant
Career Interest in ECE	18	3.09	3.48	0.39	Paired t-test	t = 1.58	0.132	d = 0.37	Not Significant
Overall Score	18	3.15	3.65	0.50	Paired t-test	t = 2.47	0.024	d = 0.58	Significant

The paired inferential results strengthen the descriptive findings. Statistically significant gains were observed in Awareness of ECE, Robotics Learning Perception, Self-Efficacy, and the Overall Score. These findings indicate that the robotics demonstration did more than simply produce favorable impressions; it was associated with measurable improvement in students' understanding of ECE-related ideas, perception of robotics as an engaging learning medium, and confidence in performing technical tasks. The effect sizes ranged from moderate to moderate-to-strong, suggesting that these gains were not trivial. By contrast, Perceived Value and Career Interest showed positive numerical gains but did not reach statistical significance in the matched subset. This result should be interpreted cautiously rather than negatively. It likely reflects the short duration of the intervention and the small, matched sample size. Changes in value perception and career interest are often slower to stabilize than immediate outcomes such as engagement and confidence. In the context of an advocacy-oriented pilot, movement from unfamiliarity to curiosity and from hesitation to tentative openness may already be considered meaningful. Item-level paired analysis further clarified where statistically significant changes occurred.

Table 11. Selected significant item-level paired findings

Item	Indicator	Pre mean	Post mean	Gain	Test used	p-value	Interpretation
Q7	Understands careers Electronics Engineers can pursue	2.89	3.56	0.67	Wilcoxon	0.042	Significant increase
Q9	Robotics activities make learning more	3.28	4.11	0.83	Paired t-test	0.017	Significant increase

Item	Indicator	Pre mean	Post mean	Gain	Test used	p-value	Interpretation
	interesting and engaging						
Q11	Robotics connects science and mathematics to real-world applications	3.11	3.78	0.67	Paired t-test	0.029	Significant increase
Q14	Capability to learn basic programming used in robotics	3.06	3.72	0.67	Wilcoxon	0.018	Significant increase
Q15	Belief in successfully completing robotics or automation tasks	2.94	3.61	0.67	Wilcoxon	0.018	Significant increase

These item-level findings confirm that the pilot was particularly effective in making learning more engaging, clarifying ECE careers, highlighting real-world relevance, and strengthening students' confidence in programming and technical task completion. These represent core outcomes for an introductory advocacy intervention.

3.5.4 Thematic analysis of posttest reflections

To complement the quantitative findings, open-ended posttest reflections were analyzed using descriptive thematic content analysis. The purpose of this analysis was not to construct deep latent meanings, but to identify recurring content patterns in what students found most interesting and what they reported learning from the demonstration. The dominant themes that emerged were coding/programming, wiring and circuit connection, hands-on or simulation-based activity, and electronics and robotics concepts.

Table 12. Summary of themes from posttest reflection responses

Reflection area	Emerging themes
Most interesting part of the demonstration	Coding/programming; wiring and circuit connection; hands-on or simulation-based activity; electronics and robotics tasks
New concepts learned	Connecting wires; coding/programming; basic circuit behavior; electronics and robotics concepts
Overall pattern	Students were most engaged by practical, interactive, and skill-based aspects of the activity

The most frequently recurring theme was coding/programming, indicating that students perceived programming as interesting and approachable rather than overly abstract. Wiring and circuit connection was another strong theme, showing that physical manipulation of components was central to student engagement. The recurrence of hands-on or simulation-based activity further supports the interpretation that the effectiveness of the demonstration lay in its practical and participatory structure. Finally, students' references to basic electronics and robotics concepts suggest that the activity provided not only motivational value, but also accessible technical learning. These thematic results reinforce the quantitative findings. Students most often described the experience in terms of doing, connecting, testing, and understanding through action, which is consistent with the domain-level and item-level improvements in engagement, learning perception, and self-efficacy. At the same time, the reflection data suggests that the intervention's strongest effects were immediate and experiential, while

broader disciplinary or professional meanings may require more explicit framing in future implementations.

3.5.5 Posttest interest in learning more about electronics engineering

The posttest also included a direct question asking whether students were more interested in learning about Electronics Engineering after the activity.

Table 13. Posttest response to interest in learning more about electronics engineering

Response	Frequency	Percentage
Yes	13	34.2%
Maybe	20	52.6%
No	1	2.6%
Blank / unclear	4	10.5%
Total	38	100.0%

More than half of the respondents selected "Maybe," while about one-third selected "Yes." Only one respondent answered "No." This distribution suggests that the pilot was effective in opening students' interest toward Electronics Engineering, even if many remained in the exploratory rather than fully committed stage. In advocacy-oriented interventions, movement from low awareness or uncertainty toward curiosity and openness is already a meaningful outcome. The results therefore suggest that the demonstration served as a successful bridge between unfamiliar technical concepts and possible future academic or career pathways.

The final Robotics-Based Advocacy Framework for Electronics Engineering was synthesized through a sequential integration of the preceding analytical stages. First, the Kano analysis identified the satisfaction structure of the 25 robotics learning attributes, distinguishing those that functioned as motivational amplifiers from those that served as basic or stabilizing conditions. Second, the Better–Worse coefficient analysis clarified the relative strategic weight of these attributes by showing which features most strongly increased student satisfaction when present and which carried the greatest dissatisfaction risk when absent. Third, the Importance–Performance Analysis (IPA) prioritized the attributes according to their strategic importance and current delivery, identifying which features should be maintained, strengthened, or given focused attention. Fourth, Quality Function Deployment (QFD) translated these prioritized learner-valued attributes into institutional design requirements, thereby converting student voice into a structured program architecture. These outputs provided an empirical pathway from learner perceptions to design priorities, which were then synthesized into the major dimensions of the proposed framework. The pilot robotics demonstration did not define the structure of the framework itself; rather, it provided preliminary support for the practical relevance of the advocacy directions generated through the KANO–IPA–QFD sequence.

3.6 Final robotics-based advocacy framework for electronics engineering

The Robotics-Based Advocacy Framework for Electronics Engineering was derived from the converging results of the Kano analysis, better–Worse coefficient analysis, Importance–Performance Analysis (IPA), and Quality Function Deployment (QFD). Rather than being formed through conceptual grouping alone, the framework emerged through a sequential synthesis of empirical findings. Kano analysis first identified the type of value associated with each robotics learning attribute. Better–Worse analysis then clarified the relative strategic weight of these attributes by indicating which features most strongly increased student satisfaction and which carried the greatest dissatisfaction risk

when absent. IPA subsequently showed which attributes were already functioning strongly and which required focused enhancement. QFD then translated these learner-valued priorities into institutional design requirements. Through this progression, the study moved from student-valued attributes to priority advocacy factors, to institutional design directions, and finally to the layered structure of the proposed framework.

At the foundation of the framework is the Experiential Core. This layer was elevated as the base of the framework because the strongest motivational findings consistently pointed to hands-on and confidence-building robotics experiences. In the Kano results, hands-on robot building and assembly (F10), sensor integration activities (F13), and confidence-building robotics tasks (F33) were the only attributes classified as Attractive, indicating that they functioned as the clearest motivational amplifiers within the robotics advocacy environment. Their Better coefficients were also among the highest in the dataset, confirming their strong satisfaction-enhancing potential. In the IPA results, these attributes were positioned in Quadrant I, showing that they were not only highly valued but also already well delivered. This same pattern carried into QFD, where Experiential Robotics Ecosystem (H7) emerged as the highest-ranked institutional design requirement at 64.5422 (22.32%). These results justify the placement of experiential robotics learning at the core of the framework. This layer contributes to advocacy design by making Electronics Engineering visible, interactive, and attainable through direct engagement, thereby helping students develop early interest and a stronger sense of technical capability.

The second layer is the Structured Curriculum Layer. This dimension emerged from the consistent finding that student engagement must be supported by instructional clarity and coherent learning organization. Although features such as clear learning modules and tutorials (F31), adequate time for robotics sessions (F32), and step-by-step scaffolding (F15) were not classified as Attractive in absolute Kano terms, the Better–Worse analysis showed that they carried substantial strategic value, particularly in preventing dissatisfaction and stabilizing the learning experience. Most notably, F31 recorded the most negative Worse coefficient (-23.36%), indicating that unclear instructional structure posed the greatest dissatisfaction risk when absent. In the IPA results, F31 and F32 were in Quadrant I, confirming both their strategic importance and their strong delivery. In the QFD stage, this pattern was translated into Structured Curriculum Framework (H3), which ranked second overall at 54.9790 (19.02%). These findings justify the inclusion of a distinct curriculum layer in the framework. This layer contributes to advocacy design by ensuring that robotics experiences remain understandable, properly sequenced, and developmentally supportive rather than overwhelming or fragmented.

The third layer is the Support and Guidance Layer. This dimension was derived from findings showing that effective robotics advocacy depends not only on activities and materials, but also on the people and support systems that help students interpret those experiences meaningfully. In the IPA results, teacher competency in robotics facilitation (F27), career talks from robotics or electronics professionals (F25), and mentorship from engineers or robotics experts (F26) were all positioned in Quadrant I, indicating that these support-related features were both highly valued and well delivered. Better–Worse analysis also showed that these attributes carried meaningful satisfaction-enhancing value, even when not classified as Attractive under absolute Kano categorization. In the QFD stage, these results were translated into the institutional priorities of Faculty Development (H4), ranked third at 31.5294 (10.91%), and Mentorship and Industry Linkages (H2), ranked fourth at 30.0270 (10.39%). These findings justify why support and guidance were elevated into a separate framework dimension. This layer contributes to advocacy design by providing contextual support through which students can connect robotics engagement with confidence, encouragement, and clearer academic or career direction in Electronics Engineering.

The top layer is the Career, Community, and Visibility Alignment Layer. This dimension emerged because the results showed that advocacy should not end with engagement alone; it must also connect robotics to broader purpose, social relevance, and future identity. The strongest indicator of this need was community-centered robotics (F22), which was the only attribute located in Quadrant II (Concentrate Here) in the IPA results, making it the most important underperforming advocacy feature in the dataset. This finding showed that students valued robotics activities that addressed real community problems, but that this dimension was not yet being delivered at a level that matched its strategic potential. Additional support for this layer came from attributes related to ECE connection (F23), orientation on ECE specializations (F24), and opportunities to showcase robotics projects (F34), which, although placed in lower-priority quadrants, still represented important advocacy directions concerned with professional identity, visibility, and future pathway recognition. In the QFD results, these concerns were translated into Community Integration (H1), ranked fifth at 28.7198 (9.93%), Career Pathway Integration (H6), ranked sixth at 28.1560 (9.74%), and Showcase Platform (H8), ranked seventh at 27.6252 (9.56%). These findings justify the inclusion of a final alignment layer that links robotics experiences to societal contribution, disciplinary meaning, and visibility. This layer contributes to advocacy design by helping students see Electronics Engineering not only as something they can do, but also as something relevant to communities, future careers, and personal aspiration.

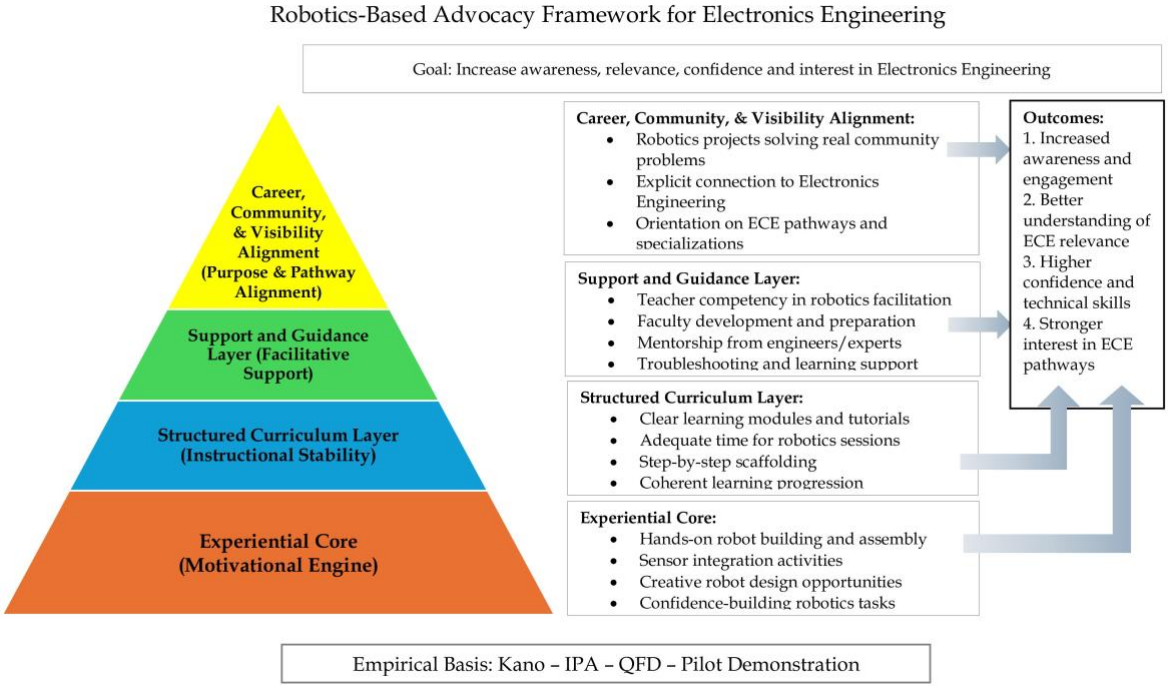

Figure 4. Robotics-based advocacy framework for electronics engineering

The four layers shown in Figure 4 reflect a traceable empirical progression from the results tables to the final framework structure. The Experiential Core was supported by the Attractive Kano attributes and the highest-ranked QFD priority. The Structured Curriculum Layer was supported by the strong Worse coefficients and high QFD priority of instructional organization. The Support and Guidance Layer was supported by Quadrant I support-related attributes and the QFD ranking of faculty and mentorship requirements. The Career, Community, and Visibility Alignment Layer was supported by the sole Quadrant II attribute and the mid-level QFD priorities related to community integration, career pathways, and showcasing. In this way, the framework represents not merely a conceptual model, but a learner-centered advocacy architecture directly synthesized from the sequential Kano–

IPA–QFD findings, with the pilot robotics demonstration serving only as preliminary support for its practical relevance.

3.7 Limitations of the study

This study should be interpreted in light of several limitations. First, the framework was developed using purposive sampling, which was appropriate for identifying learner-valued robotics attributes from students exposed to robotics-based advocacy activities, but which also limits the generalizability of the findings beyond the specific participant group involved in the study. Second, the study was conducted within the context of partner secondary schools, and the resulting framework therefore reflects the educational conditions, learner profiles, and implementation realities of those specific settings. While this context-based grounding strengthens the practical relevance of the framework, it also means that the results should not be assumed to represent all secondary school environments in the Philippines without further validation. Third, the framework is grounded largely in student self-report data, including perceptions of valued robotics attributes, learning experiences, confidence, and interest. Although these perceptions are central to advocacy design, self-report measures may be influenced by response tendencies, immediate impressions, or situational factors. Fourth, the pilot implementation evidence remains preliminary. The robotics demonstration was designed as an introductory advocacy activity rather than a full intervention or long-term curriculum, and its role in the study was limited to providing initial support for the practical relevance of the proposed framework. Fifth, the paired inferential analysis of the pilot used a smaller matched subset than the broader framework-development dataset, which limits the strength of the statistical conclusions that can be drawn from the pilot phase. Accordingly, future studies should validate and refine the framework across other school contexts, larger participant groups, and longer-term implementations. Additional work may also examine how the framework performs when applied in different institutional settings, learner populations, and program models, and whether its advocacy effects are sustained over time.

4. Conclusion

This study developed a Robotics-Based Advocacy Framework for Electronics Engineering by integrated KANO–IPA-QFD approach. By identifying student-valued robotics learning attributes, prioritizing their strategic importance, and translating them into institutional design requirements, the study moved systematically from learner perceptions to a structured, learner-centered advocacy framework for Electronics Engineering. The resulting framework highlights four interrelated dimensions: Experiential Core, Structured Curriculum Layer, Support and Guidance Layer, Career, Community, and Visibility Alignment Layer. These dimensions indicate that effective advocacy for Electronics Engineering should not rely on isolated demonstrations or general promotion alone but should be organized as a coherent system that combines engaging robotics experiences, instructional clarity, human support, and visible links to purpose, community relevance, and future pathways.

The study's primary contribution lies in showing how robotics can be positioned not only as a pedagogical tool but also as a designable advocacy mechanism for strengthening interest in a specific engineering discipline. Through the KANO–IPA–QFD sequence, the framework provides an empirical basis for determining which aspects of robotics learning should be preserved, strengthened, and translated into institutional action. In this sense, the study contributes both a methodological pathway for advocacy framework development and a practical model for school- and institution-based ECE promotion initiatives. The pilot robotics demonstration provided preliminary support for the practical relevance of the proposed framework by showing positive short-term movement in student awareness, learning perception, and confidence. However, the study does not claim full validation or

long-term effectiveness. Rather, it offers a theory-informed, learner-centered, and data-driven basis for designing Electronics Engineering advocacy initiatives, which future studies may further examine across broader contexts, larger participant groups, and longer implementation periods.

Author's declaration

Author contribution

Helen Grace B. Gonzales conceptualized the study, designed the research methodology, conducted data collection and analysis, and prepared the manuscript. **Consorcio S. Namoco Jr.** supervised the research process, contributed to the theoretical framework development, and reviewed the manuscript. **Alenogines L. San Diego** contributed to the data validation, methodological review, and manuscript editing.

Funding statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request. Data sharing is limited in order to protect participant privacy, as the respondents include secondary school students. Aggregated data used for analysis are included within the article and its supplementary materials.

Acknowledgements

The authors express their gratitude to the University of Science and Technology of Southern Philippines (USTP) and the partner secondary schools that supported the pilot robotics demonstration. The authors also acknowledge the teachers and students who participated in the study and contributed valuable insights to the development of the Robotics Advocacy Framework.

Conflict of interest

The authors declare that there are no competing interests regarding the publication of this paper.

Ethical clearance

This study complied with the Declaration of Helsinki and the ethical research standards of University of Science and Technology of Southern Philippines, with institutional approval obtained, voluntary informed participation, and strict protection of participants' anonymity and confidentiality through anonymized and aggregated data reporting.

AI statements

The grammatical structure of this article was improved using Grammarly. The authors manually reviewed and validated all generated corrections to ensure accuracy and appropriateness of the language used in this manuscript. The research data, analysis, and interpretations presented in this article are the original work of the authors.

Publisher's and Journal's Note

Researcher and Lecturer Society as the publisher, and the Editor of Innovation in Engineering state that there is no conflict of interest towards this article publication.

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