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ROBOTICS LITERACY DEVELOPMENT IN THE 21ST CENTURY ERA: A QUANTITATIVE STUDY ON THAILAND TECHNICAL COLLEGE STUDENTS

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Research Paper

Abstract: *The aim of this study was to investigate the human resource development among vocational college students in the context of Robotics Literacy Development (RLD) during the 21st Century. Data was gathered through a survey questionnaire administered to 1000 vocational college students using proportional sampling techniques. Quantitative analysis using SPSS encompassed both descriptive and inferential statistics. The study revealed that demographic factors such as sex and academic level had no significant impact on RLD levels, indicating no discernible differences in RLD based on these variables. However, factors such as robotics system learning status, types of learning about robotic systems, objectives of robot learning, and the perceived necessity of robotics-related internships showed significant and positive correlations with RLD, highlighting their influence on RLD levels. The study contributes theoretically by extending existing models and providing significant findings that enrich the current literature. Practically, the findings are relevant for policymakers, aligning with governmental initiatives on RLD and underscoring the ongoing need to enhance human resources development to ensure vocational graduates' competencies meet market demands.*

Keywords: *Vocational Education, Human Resource Development, Robotics Literacy*

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1. Introduction

In the era of 21st-century globalization, marked by significant advancements in science, technology, and digital fields, every facet of modern society has been profoundly impacted (Barakina et al., 2021; Bruhn-Zass, 2020). These rapid advancements encompass innovations such as artificial intelligence, robotics, drones, modern genetic technologies, social media platforms, and financial technologies, which are anticipated to play pivotal roles in enhancing human convenience and fostering robust economic growth in the foreseeable future (Arkaraprasertkul, 2023). According to the National Science and Technology Development Agency (NSTDA) (2020) report titled "Thailand's Robotics Industry," the global deployment of robots has surged significantly since 2015, marking a transformative shift. This expansion not only includes industrial robots but also spans autonomous vehicles, consumer service robots, business automation systems, medical robotics, military applications, and Unmanned Aerial Vehicles (UAVs). By 2020, the emphasis will be on delineating the roles and functionalities of robots and artificial intelligence (AI). Research conducted by the U.S.-based firm Tractica (https://www.tractica.com) forecasts a substantial rise in robot production, from 8.8 million units in 2015 to 61.4 million units by 2020, with more than half serving as consumer robots for households. The global robotics industry is projected to surpass a market value of USD 151 billion by 2020. In recent times, Thailand has strategically invested in robotics to bolster manufacturing processes and enhance global competitiveness. The expansion of Thailand's industrial robotics sector has been notable, experiencing a remarkable 133% growth from 2,131 units in 2013 to 7,500 units by 2018. According to a 2015 report by World Robotics and the International Federation of Robotics (IFR), Thailand ranked as the 8th largest importer of industrial robots globally. Assessments of the technological proficiency among users of Thai robotics and automation systems indicated that a majority (60%) function solely as operators, while a mere 5% of Thai entrepreneurs possess the capability to develop sophisticated robots and automation systems, particularly in the domain of service robotics, owing to a scarcity of highly skilled developers (Plumwongrot & Pholphirul, 2023).

This data underscores the imperative and significance of continual monitoring and promotion of robotics to enhance productivity, diversify product offerings, and meet evolving service demands across various industries (Ramasoota, 2022). The progression of automation, encompassing robotics and machinery aimed at augmenting efficiency, is increasingly employed in sectors such as agriculture, research and development, exploration, and beyond, profoundly transforming human existence and influencing contemporary educational paradigms that necessitate adaptation to cultivate human capital in sync with contemporary needs (Bruhn-Zass, 2020; Lee & Lee, 2021; Phetthianchai, 2022; Tripak, 2016). Acknowledging this significance, nations have recognized the pivotal role of technology, innovations, AI, and robotics in propelling national advancement. Central to this progress is the cultivation of human resources equipped with competencies tailored to the demands of the new era, ensuring their knowledge, skills, and capabilities are effectively deployed on a national scale (Frolova et al., 2020; Insuwan, 2019). Governments are implementing policies, strategic frameworks, and initiatives to support research and human capital development endeavours, underpinned by robust plans aimed at preparing for the unfolding industrial revolution (Arkaraprasertkul, 2023). They advocate for educational advancement towards their vision through the expedited adoption of technology-focused learning strategies tailored for academically proficient students (Bruhn-Zass, 2020). Curriculum development across educational tiers emphasizes the integration of technology, innovations, AI, and robotics into academic subjects, with the objective of augmenting competencies in knowledge, skills, and abilities. Concurrently, structured training initiatives in these domains, alongside technical, vocational, and preparatory education, are being established with defined objectives and heightened collaboration between academic institutions and industry stakeholders (Lee & Lee, 2021).

Nevertheless, despite the integration of robots with human labour in the industrial sector, research indicates that the utilization of robots alongside human workers in Thailand remains lower compared to industrialized nations overseas (Ramasoota, 2022). This disparity in robot adoption within Thai manufacturing may stem from factors such as production base relocation, adaptations in manufacturing processes, and enhancements in labour productivity. Moreover, the limited availability of educational institutions nationwide offering robotics courses and training contributes to a shortage of skilled robotics labour (Marknual, 2019). Therefore, it is imperative to foster readiness among educational institutions to support the growth of the robotics industry and the cultivation of skilled labour, particularly among vocational students who represent the next generation poised to enter the workforce and play a pivotal role in the nation's future development (Insuwan, 2019). Equipping vocational students with robotics competencies is crucial for all stakeholders, encompassing educational institutions, policymakers, educators, and parents, who must collaborate to instil these foundational skills through varied instructional approaches. Developing students' proficiency in robotics, fostering creative thinking, and decision-making, problem-solving, and effective communication also necessitates organizational backing from both educational entities and private sectors. This entails supervisor support, recognition and incentives, opportunities for project creation, autonomy in tasks, encouragement of continuous learning, and an organizational framework conducive to growth, motivating students to become more proficient contributors to the workforce (Education, 2016).

Given the aforementioned rationales, the issue of enhancing technical college students' knowledge and skills in the 21st century has emerged as a focal point: a case study examining feedback on the augmentation of robotics knowledge and skills (Phetthianchai, 2022). The study aims to collect student feedback with the objectives of (1) assessing and contrasting levels of Vocational/College Student Characteristics (VSC) and RLD, and (2) exploring the correlation between VSC and RLD. The research outcomes are intended to serve as a blueprint for the Office of Vocational Education Commission in crafting policies that bolster VSC and RLD aligned with the 2019 National Vocational Qualification Framework set forth by the Ministry of Education, thus staying abreast of contemporary trends (Sukhampha & Kaasch, 2023). This study contributes significant insights to existing literature, informing educational practices and policymaking. Educational institutions stand to benefit by prioritizing active learning methodologies and refining curricula to harmonize with industry standards and technological advancements. Additionally, policymakers should contemplate fostering increased collaboration between educational institutions and industry stakeholders to facilitate impactful internship opportunities that enhance students' practical competencies. Therefore, incorporating these insights into practice enables stakeholders to adeptly cultivate a proficient workforce capable of navigating and innovating within the continuously evolving realm of robotics and related disciplines. This ensures that vocational students are well-prepared for successful careers in today's dynamic, technology-driven world. The remainder of the paper is structured into four additional sections: literature review, research methods, data analysis and results, and discussion and research implications.

2. Literature Review

2.1 Theoretical Review

2.2.1 Need and Support Robotics Literacy Development (RLD) in Vocational and High Vocational Education Program

In the competitive landscape of the 21st century, the demand for vocational education has surged in tandem with Thailand's economic expansion and foreign investments. It is evident that contemporary organizations are increasingly integrating technology into intricate tasks. This evolution necessitates that employees exhibit flexibility, adeptness in managing uncertainty and change, possess requisite skills and competencies, and perform effectively (Phuanpoh, 2019). Within modern education, this serves as the foundational premise for integrating technology, innovations, AI, and robotics into current learning frameworks (Barakina et al., 2021; Frolova et al., 2020). RLD embodies the integration of workforce competencies to meet the demands posed by robotics systems, aligning with the educational conceptual framework outlined in the Thai National Education Plan 2017-2018 (Education Council Secretariat Ministry of Education, 2017). Educational institutions are tasked with embracing and effectively operationalizing these principles and concepts, whether through policy backing for educational administration, curriculum enhancement, faculty professional development, pedagogical strategies, or extracurricular engagements. These endeavours are designed to guarantee that learners attain and proficiently apply the skills and knowledge imparted to them (Insuwan, 2019). Assessment of robotics literacy development can be structured around the following components.

2.2.2 College Support and Promotion of Student Skills Competitions (CSPS)

Employee performance significantly influences organizational success. Employees who perceive their individual achievements as meeting expectations and fulfilling key performance indicators across diverse dimensions contribute positively to organizational outcomes (Panthukampone & Chienwattanasook, 2019). Support and recognition, which involve publicly acknowledging employees' successes both within and outside the organization, enhance perceptions of organizational support and validate employees' contributions, fostering a sense of value (Phuanpoh, 2019). Moreover, when organizations provide opportunities for employees to leverage their knowledge, skills, and potential in challenging assignments, it promotes career progression and enhances the organization's competitiveness in the business environment (Panthukampone & Chienwattanasook, 2019). The CSPS factor thus evaluates the public acknowledgment of learners' accomplishments, particularly in demonstrating their robotic skills within the educational context. This recognition, especially concerning robotics skills, contributes significantly to the overall success of the institution and its educational programs.

2.2.3 Support of the College's Subject Heads (CSHS)

The employee perception of supervisor support involve recognizing how supervisors value their work and show concern for their well-being. Supervisors, acting as representatives of the organization, are responsible for overseeing work and evaluating performance, then relaying this information to higher management. Employees assess their supervisors' supportive actions and estimate the organization's level of support through their supervisors (Panthukampone & Chienwattanasook, 2019). Increased perceived organizational support can lead employees to desire greater involvement in the organization's success and ultimately help the organization achieve its goals (Phuanpoh, 2019). When subordinates or organizational members perceive support from their supervisors, it fosters positive feelings towards the organization and stimulates creativity to enhance work efficiency (Gok et al., 2015). CSHS represents how employees perceive their supervisors' expressions of authority in educational institutions promoting robotics-related courses.

2.2.4 Adequacy Robotics Classrooms and Laboratories (ARCL)

Adequate resource allocation is a critical determinant requiring substantial backing to realize institutional visions and goals, particularly in delivering education that cultivates advanced technological and innovative capabilities. Educational institutions must earmark adequate budgets and investments, alongside other essential resources, to enhance knowledge, skills, and competencies (Education Council Secretariat Ministry of Education, 2017). This includes fostering partnerships among academia, industry, educational collaborators, and research entities to establish a supportive network of resources (Nghia & My Duyen, 2018). Additionally, according to ARCL findings, institutions must also ensure the presence of qualified, diverse, and sufficient faculty members who continuously update curricula and course content to remain contemporary and support RLD (Sapnirund, 2016). Regarding managerial support, comprehending ARCL and utilizing it as a metric aids in identifying strategies for providing administrative backing and solutions (Saengchamnonga & Viroonratchb, 2020).

2.2.5 The College Organized Activities to Demonstrate the Use of Robots (OADR)

In the context of educational institutions, Organizational Achievement Display and Recognition (OADR) underscores the showcasing of institutional accomplishments through events or platforms that allow students, teachers, and other participants to present their work and achievements to the organization. OADR serves as a determinant influencing perceptions of organizational support, motivating employees to exhibit greater dedication and commitment to their roles (Chalapati & Chalapati, 2020). When employees can demonstrate their achievements and perceive that their contributions align with organizational objectives, and when the organization fosters and provides opportunities that meet employee expectations, it fosters positive behaviours that enhance job performance (Panthukampone & Chienwattanasook, 2019). Additionally, scholars have highlighted OADR as a crucial factor in enhancing RLD (Sapnirund, 2016).

2.2.6 Collaboration with Industrial Internship Programs (CIIP)

Internship programs play a crucial role within the educational system by providing students with opportunities to integrate acquired knowledge and skills into real-world work environments (Nghia & My Duyen, 2018). These programs are integral educational strategies for human resource development, focusing on management approaches that emphasize learning and practical skill support (AlHamad et al., 2022). The CIIP underscores alignment with essential instructional processes, including diverse teaching methodologies that promote the integration of theoretical and practical knowledge. It also emphasizes the importance of curriculum design tailored to diverse learning experiences and alignment with contemporary technology management systems. Furthermore, CIIP fosters educational partnerships with businesses to cultivate specialized labour competencies that align with current market demands (Patacsil & Tablatin, 2017; Sapnirund, 2016). Thus, CIIP exemplifies the collaborative capacity of colleges and industrial sectors willing to collaborate and support students during their internships.

2.2.7 Freedom to Design Learning Styles of Teachers and Students (FDLS)

FDLS embodies a perspective that advocates for instructional autonomy among educators and encourages students' creative independence in learning about robotic systems and control operations as outlined in the curriculum. Within educational management, this autonomy facilitates comprehensive planning from the inception of teaching strategies to performance evaluations. Research has shown that autonomy in task methods, decision-making, work scheduling, and facilitating effective learning significantly enhances operational efficiency. FDLS also reinforces perceptions of organizational support in these domains (Panthukampone & Chienwattanasook, 2019). Promoting FDLS benefits both teachers and students, empowering them to autonomously adjust the scope of learning, fostering leadership within the educational environment, and creating conditions conducive to shaping educational pathways. This approach facilitates the development and enhancement of contemporary teaching tools, thereby positively influencing the effectiveness of the educational process (Frolova et al., 2020).

2.2.8 Rewarding and Honouring Student Achievements (RHSA)

RHSA involves acknowledging and supporting students in attaining success with the assistance of their educational institutions. This practice underscores the importance of recognizing students' accomplishments, which serve as building blocks for applying knowledge acquired through their education. RHSA encompasses both monetary and non-monetary forms of recognition and support. Various forms of recognition and rewards serve as significant motivators that inspire employees to demonstrate commitment to their work, thereby enhancing work efficiency (McKenna, 2020). For educational institutions, fostering this awareness can lead to the generation of beneficial outcomes that positively impact both students and the institution (Panthukampone & Chienwattanasook, 2019). RHSA holds importance in showcasing educational institutions' capacity to enhance the value of their graduates. It also promotes perceptions of institutional support, indirectly influencing the performance of educational personnel by fostering engagement and encouraging behaviours that contribute to exemplary performance (Al-Aamri, Soliman, & Ponniah, 2024).

2.2.9 Clarity of Organizational and Curriculum Structure (COCS)

The organizational framework and formal delineation of departmental responsibilities within an organization constitute components of perceived organizational support that influence employee behaviours and attitudes (Saengchamnonga & Viroonratchb, 2020). In the educational context, the COCS defines the structure of the college's curriculum, specifying responsibilities for each curriculum area, including the development of courses related to robotic systems (Education Council Secretariat Ministry of Education, 2017). Moreover, COCS reflects the managerial hierarchy and the consistent application of methodologies in addressing the needs of educational institutions. However, organizational structures, whether formal or informal, can enhance the work environment and improve employee performance within the organization (AlHamad et al., 2022; Saengchamnonga & Viroonratchb, 2020).

2.2.10 The Vision of College Administrators and Instructors (VCAI)

VCAI pertains to the commitment of college leaders and educators in implementing and communicating the institution’s curriculum to stakeholders. This emphasizes the integration of robotic control systems into the curriculum, the utilization of robots as educational tools, and the coordination of student internships with robotics-related industries (Nghia & My Duyen, 2018; Phetthianchai, 2022; Phuanpoh, 2019). In educational management contexts, VCAI involves fostering creativity among faculty and staff, encouraging participation in the development or enhancement of teaching methodologies, and refining operational procedures (Saengchamnonga & Viroonratchb, 2020). The perceived VCAI among faculty, staff, students, and other stakeholders fosters a sense of support and recognition from leadership, which correlates with positive performance outcomes (Gok et al., 2015).

2.3 Vocational/College Student Characteristics (VSC)

Issues concerning the study of computer development, machinery, robots, and modern technology involve harnessing intelligent capabilities to make informed decisions and effectively emulate human behaviour. This underscores the increasing necessity to enhance human competency through education across various educational levels. Implementing policies that integrate diverse aspects is crucial to achieving educational success among students (Phetthianchai, 2022). Establishing guidelines to promote and develop knowledge, skills, and abilities in human resources can ensure their practical application upon graduation (Tripak, 2016). Academic studies and teaching aimed at achieving academic success, while cultivating knowledge, skills, and attitudes, facilitate cognitive processes that enable students to conceptualize, apply, and adapt content. Tailoring learning activities to individual aptitudes and needs is essential in organizing effective teaching and learning environments that motivate students and support educational sector roles in preparing future-ready human resources (Phetthianchai, 2022). However, the study identifies that students' personal characteristics also influence their learning experiences and perceptions of support across various educational domains (Panthukampone & Chienwattanasook, 2019). These characteristics can be categorized into six components: Vocational/High Vocational-Diploma Certificate Level (LEVEL), Gender (SEX), Robot System Learning Status, Learning Type About

Robotic Systems (LEARN-TYPE), Robot Learning Objectives (LEARN-OBJ), Learning Subject of Robotic Systems (LEARN-SUB), and the Necessity of Internships for Using Robot Jobs (INTERN-NEED).

2.4 Hypothesis Development

2.4.1 Vocational / High Vocational -Diploma Certificate. (LEVEL) and RLD

Education management must align with national objectives, focusing on developing human resources that support the nation's economic and social progress. This necessitates adapting teaching and learning methodologies to accommodate the diverse characteristics of learners across various educational levels and age groups. Emphasis should be placed on fostering comprehensive learning processes and advancing specialized knowledge and skills, particularly in technological fields. Technical and vocational education, as well as pre-degree programs, encompass educational models ranging from vocational certificates to bachelor's degrees (Sapnirund, 2016). In elementary education, Ching and Hsu (2023) explored the integration of robotics, highlighting its potential to enhance problem-solving skills and foster enthusiasm for STEM subjects among students pursuing different professional certificates. Conversely, (Darmawansah et al., 2023) focused on middle school education, noting that variations in educational diplomas could influence RLD through improved computational thinking. At the high school level, (Zhang et al., 2024) studied robotics competitions as drivers of advanced technical skills and career readiness, underscoring the significant influence of educational levels (LEVELS) on RLD. Therefore, based on these findings, it is hypothesized that,

H1: *Different LEVELS have different opinions on RLD.*

2.4.2 Gender (SEX) and RLD

Gender represents a significant personal factor influencing RLD, impacting learning effectiveness across classrooms, curricula, and training programs. The gender of learners or trainees can shape their educational experiences, course preferences, and career trajectories (Sapnirund, 2016). Arısoy Gedik and Ceyhan (2024) underscored gender differences in robotics interest, noting initial disparities favouring boys, potentially mitigated through supportive learning environments fostering sustained engagement and skill development among girls. In contrast, (Lin & Mubarok, 2024) suggested that societal stereotypes and the absence of female role models in robotics can impede girls' long-term engagement and confidence in the field. However, interventions promoting inclusivity and collaborative problem-solving have shown promise in reducing gender disparities and promoting equitable RLD (Parlangeli et al., 2024). These studies collectively highlight gender as a crucial factor influencing RLD. Therefore, the study proposes the following research hypothesis,

H2: *Different SEX has different opinions on RLD.*

2.4.3 Robot System Learning Status (LEARN-STA) and RLD

The LEARN-STA factor, focusing on the current learning status of students, significantly influences RLD. It examines whether students have previously engaged in related learning activities or are new to such learning experiences. This distinction affects their foundational knowledge, skills, and abilities, which are crucial for their future career applications (Barakina et al., 2021). In educational management contexts, diverse learning formats such as full-time courses, short-term vocational courses, and specialized training programs are considered essential. These programs aim to equip individuals with skills that enhance their employability or meet the demands of skilled labour requiring advanced qualifications. Moreover, technical courses and subject content are regularly updated to ensure their relevance (Sapnirund, 2016). Additionally, Ali et al. (2024) found that robotics learning status significantly enhances RLD, fostering a culture of continuous learning and personal development in professional settings. These findings underscore the importance of robotics learning status in augmenting RLD. Therefore, the study posits the following research hypothesis,

H3: *Different LEARN-STA has different opinions on RLD.*

2.4.4 Learning Type about Robotic Systems (LEARN-TYPE) and RLD

The LEARN-TYPE factor encompasses various instructional methods utilized in higher education, significantly influencing RLD. This factor includes three primary learning types related to technology, innovations, AI, and robotics: (1) Theoretical and Practical Learning, (2) Scientific Research and Experimental Learning, and (3) Specialization for Collaborative Work (Barakina et al., 2021). These learning types aim to provide a comprehensive educational experience by developing educational materials, training educators in media creation, and employing effective communication strategies. They also emphasize planning and acquiring adequate materials and equipment for teaching and training purposes to meet both quantitative and qualitative educational needs. The educational process and teaching approaches involve diverse instructional methods that integrate theoretical knowledge with practical applications, including field learning: utilizing educational and professional sites and real-world environments to enhance comprehension. This approach provides actual equipment and opportunities for hands-on practice, facilitates internships, and vocational training to ensure learners can apply their knowledge in real-world scenarios (Sapnirund, 2016). A hypothesis can be succinctly summarized regarding the variance in LEARN-TYPE that:

H4: *Different LEARN-TYPE has different opinions on RLD.*

2.4.5 Robot Learning Objectives (LEARN-OBJ) and RLD

LEARN-OBJ pertains to the educational goals set within technical vocational programs to cultivate technical competencies aligned with market demands. These objectives are pivotal in ensuring learners acquire comprehensive knowledge and practical skills relevant to their specific courses of study. They are supported by both governmental and private sectors to foster requisite knowledge and skills. Regional strategies necessitate alignment with curriculum frameworks. Organizational support functions should also possess knowledge and understanding of learning levels to enhance skills that enable LEARN-OBJ to impact RLD (Vocational Education Commission, 2020). Moreover, Han et al. (2024) examined the impact of LEARN-OBJ on RLD in middle school robotics curricula. Their findings underscored that well-defined objectives, such as programming specific robot functions or understanding sensor applications, significantly enhanced students' technical proficiency and problem-solving capabilities. Additionally, Han et al. (2024) highlighted the importance of aligning learning objectives with age-appropriate developmental stages to deepen students' comprehension of robotics concepts and enhance RLD. These studies underscore LEARN-OBJ's integral role in fostering RLD. Therefore, the study formulated the following hypothesis,

H5: *Different LEARN-OBJ has different opinions on RLD.*

2.4.6 Learn Subject of Robotic systems (LEARN-SUB) and RLD

The variables studied in relation to robot systems and RLD encompass courses offered at the Vocational Certificate and Advanced Vocational Certificate levels in fields such as Mechatronics and Robotics. Similarly, Han et al. (2024) investigated the impact of teaching specific robotics concepts like kinematics and control algorithms on high school students. Their research indicated that integrating these subjects into the curriculum enhanced students' technical proficiency and their ability to innovate within robotics projects. Conversely, Wu et al. (2023) explored the effects of project-based learning in elementary school education, focusing on subjects such as robot design, programming, and problem-solving. They found that engaging in hands-on projects improved students' critical thinking skills and their interest in RLD. In another study, Wu et al. (2023) investigated the correlation between developing computational thinking skills and robotics literacy among middle school students. Their findings suggested that structured instruction in computational concepts, such as algorithms and logical reasoning within robotics applications, notably improves RLD. Therefore, based on prior research, it is hypothesized that,

H6: *Different LEARN-SUB has different opinions on RLD.*

2.4.7 The Necessity of Internships for Using Robot's Job (INTERN-NEED) and RLD

Studies acknowledge the role of apprenticeships in allowing learners to solidify existing knowledge and skills, particularly in professions requiring specialized expertise tailored to specific occupational demands. This underscores INTERN-NEED as a pedagogical tool capable of influencing students' attitudes and learning behaviours. Research has also identified that students' involvement in internship activities can impact their learning outcomes significantly ((Nghia & My Duyen, 2018). Similarly, INTERN-NEED contributes to RLD by enhancing labour competencies, equipping students with the necessary knowledge and technical skills to pursue careers aligned with labour market demands (Patacsil & Tablatin, 2017). Moreover, (Wu et al., 2023) investigated the effects of internship experiences on higher education students participating in robotics clubs. They observed that students engaged in internships alongside robotics professionals demonstrated marked improvements in technical skills, problem-solving abilities, and confidence in applying theoretical knowledge to practical contexts. In a separate study, (Suarez et al., 2023) delved deeper into the influence of industry-sponsored internships on college students specializing in robotics engineering. Their findings demonstrated that these internships offered students practical experience and exposed them to cutting-edge technologies and practical challenges in the field of robotics development. Therefore, based on the relationships observed in previous studies, it is hypothesized that,

H7: *Different INTERN-NEED has different opinions on RLD.*

In summary, the hypothesis testing examined the relationship between VSC and RLD.

H8: *VSC is related to RLD.*

3. Research Framework

Studying concepts and related research has culminated in the development of the Research Framework depicted in Figure 1.

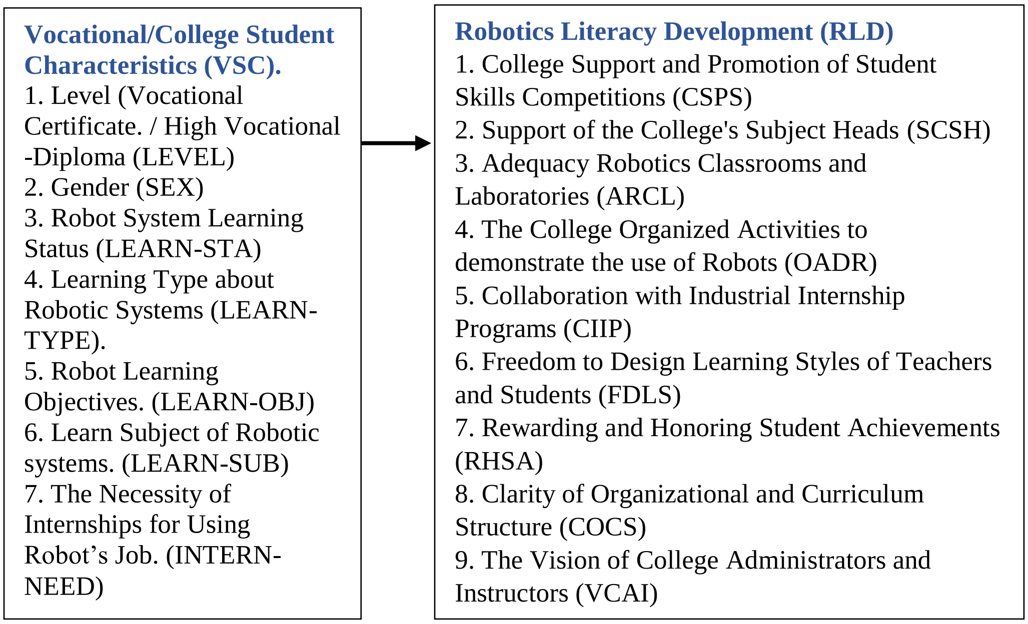

Figure 1: Research Framework

3.1 Research Method

3.1.1 Population and Sample

This study employs quantitative research methods involving vocational students within educational institutions under the Ministry of Education for the year 2023, totalling 1,379,761 individuals (Ministry of Education, 2023). The survey included a sample of 1000 participants selected through proportional stratified random and simple random sampling techniques conducted in Thailand.

3.2 Data collection and Analysis

The quantitative survey instrument utilized in this research included questions pertaining to VSC, encompassing variables such as SEX, LEVEL, LEARN-STA, LEARN-TYPE, LEARN-OBJ, LEARN-SUB, and INTERN-NEED, as well as RLD, which comprised CSPS, CSHS, ARCL, OADR, CIIP, FDLS, RHSA, COCS, and VCAI. Each variable was assessed using 5-point Likert scales, with items meeting a criterion of expert consensus and an Index of Objective Congruence (IOC) exceeding 0.6 (Trakman et al., 2017). The questionnaires demonstrated high internal consistency with Cronbach's Alpha coefficients exceeding .955 (Hair et al., 2010). Data analysis employed descriptive statistics, ANOVA, and Multiple Regression Analysis (MRA).

3.3 Research Result

Figure 2 presents the descriptive statistics of VSC (Type, n, %).

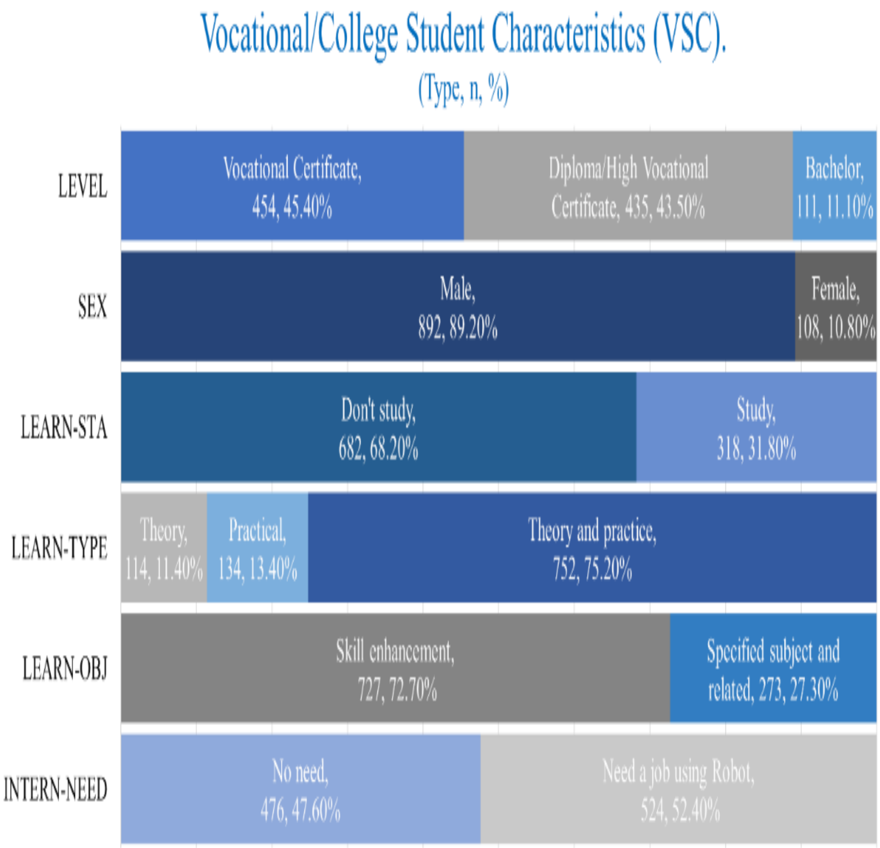

Figure 2: Vocational/College Student Characteristics. (n=1,000)

Figure 2 reveals that the majority of the sample group consisted of individuals at the Vocational Certificate Level (45.40%) and at the Diploma/High Vocational Certificate level (43.5%). The descriptive data indicate that 89.20% were male, 68.20% were not studying robot system learning (LEARN-STA), 75.72% were engaged in theory and practice learning types related to robotic systems (LEARN-TYPE), 72.70% were focused on robot learning objectives for skill enhancement (LEARN-OBJ), and 52.40% perceived internships with robot job applications as necessary (INTERN-NEED).

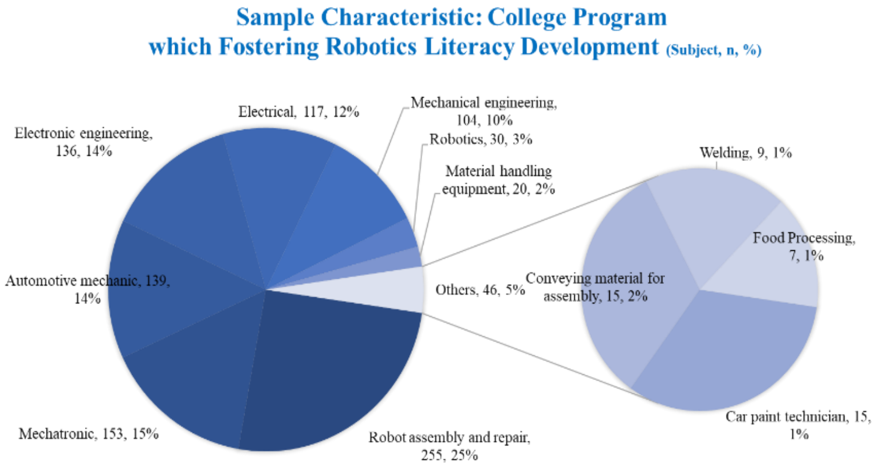

Figure 3: Sample Characteristic: College Program with RLD

According to Figure 3, the survey sample indicated that vocational certificate, high vocational certificate, pre-bachelor's degree, and bachelor's degree level courses predominantly include learning about robot systems. Specifically, robot assembly and repair accounted for 25%, followed by mechatronics at 15%, automotive mechanics at 14%, electronic engineering at 14%, electrical engineering at 12%, mechanical engineering at 10%, and other courses at 5%.

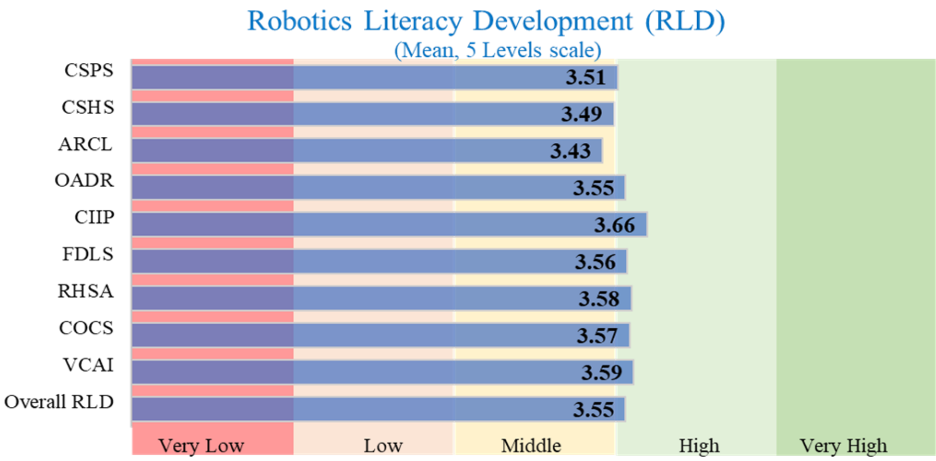

Figure 4: Levels of Opinions on RLD of the Sample Students n = 1,000

According to Figure 4, the overall RLD was rated as "High" (Mean = 3.55). The study's findings from student opinions on the 9 indicators suggest that overall RLD and 7 specific factors—CIIP, VCAI, RHSA, COCS, FDLS, OADR, and CSPS—are also rated at the "High" level. However, two factors, CSHS and ARCL, are rated at the "Middle" level. While the overall RLD is deemed "High," these results highlight the need for aligning operational perceptions with strategic goals to ensure ongoing development of human resources in line with government policies. Continued systematic management is essential to enhance competencies in RLD through factors such as CIIP, VCAI, RHSA, COCS, FDLS, OADR, and CSPS.

Table 1. Summary Result of T-Test and ANOVA-LSD (F-Test) among the Factors of VSC and Levels of Opinions on RLD

RLD	Personal and Robot Learning Characteristics						
	LEVEL	SEX	LEARN				INTERN-NEED
			STA	TYPE	OBJ	SUB	
CSPS	✔	-	✔	✔	✔	✔	✔
CSHS	✔	-	✔	✔	✔	✔	✔
ARCL	✔	-	✔	✔	✔	✔	✔
OADR	✔	-	✔	✔	-	✔	✔
CIIP	✔	✔	✔	✔	✔	✔	✔
FDLS	✔	-	✔	✔	✔	✔	✔
RHSA	✔	-	✔	✔	✔	✔	✔
COCS	✔	-	✔	✔	✔	✔	✔
VCAI	✔	-	✔	✔	✔	✔	✔
Overall RLD	✔	-	✔	✔	✔	✔	✔

Remark: - = Not found difference, ✔ = Found differences between group.

Table 1 presents the results of t-tests and ANOVA-LSD (F-tests) examining the factors within VSC, which include LEVEL, SEX, LEARN-STA, LEARN-TYPE, LEARN-OBJ, LEARN-SUB, and INTERN-NEED. Significant differences were observed among these factors in relation to RLD. In summary, varying levels of VSC factors such as LEVEL, LEARN-STA, LEARN-TYPE, LEARN-OBJ, LEARN-SUB, and INTERN-NEED are associated with differing perceptions of RLD, with statistical significance at the 0.05 level.

Table 2. Test Result of Pearson Correlation between the VSC Variable and RLD Variable

	SEX	LEARN_STA	LEARN_TYPE	LEARN_OBJ	LEARN_SUB	INTERN NEED	Overall RLD
LEVEL	-.062*	.145**	-.020	.103**	-.026	-.013	.084**
SEX		-.065*	-.052	.033	.020	-.062	-.008
LEARN_STA			.080*	.184**	-.245**	.135**	.311**
LEARN_TYPE				-.100**	.077*	.141**	.158**
LEARN_OBJ					-.168**	.063*	.120**
LEARN_SUB						-.025	-.027
INTERN_NEED							.223**

*, **. Correlation is significant at the 0.05, and 0.01 level (2-tailed).

Table 2 indicates that overall RLD exhibits Pearson's correlations with VSC variables ranging from -.245** to .311**, which are below +0.7, and all Variance Inflation Factors (VIF) are < 10. This suggests that there are no issues of multicollinearity among the variables (Koo & Li, 2016). Multiple Regression Analyses (MRA) were conducted accordingly, and the results are presented as follows:

According to Table 3, it was observed that the VSC variables significantly predict overall RLD. The overall relationship is explained by 14.6% (F = 25.371, Sig = .000). Specifically, LEARN_STA (Beta = .272, t = 8.713, Sig = .000), LEARN_TYPE (Beta = .118, t = 3.946, Sig = .000), LEARN_OBJ (Beta = .074, t = 2.428, Sig = .015), and INTERN_NEED (Beta = .169, t = 5.645, Sig = .000) show statistically significant positive influences. The standard Multiple Regression Analysis (MRA) equation can be formulated as follows:

Overall RLD = .272 * LEARN_STA + .118 *LEARN_TYPE + .074 * LEARN_OBJ + .169 * INTERN_NEED

Table 3. Multiple Regression Analyses: Relationship of VSC Factor on Overall RLD

MRA of Various Factors on Overall RLD	B	Beta	t	Sig.
(Constant)	1.359	-	6.077	.000
LEVEL	.065	.044	1.484	.138
SEX	.081	.026	.874	.382
LEARN_STA	.574	.272	8.713	.000
LEARN_TYPE	.171	.118	3.946	.000
LEARN_OBJ	.162	.074	2.428	.015
LEARN_SUB	.013	.048	1.966	.048
INTERN_NEED	.332	.169	5.645	.000
F (Sig)		25.371 (.000)		
R square		.152		
Adjust R Square		.146		

4. Discussion

RLD is critical as it provides individuals with indispensable skills in programming, engineering, and problem-solving, crucial in today's technology-driven world. Vocational/College Student Characteristics (VSC) play a pivotal role in enhancing students' RLD by offering educational pathways tailored to diverse learning styles, interests, and career aspirations, thereby establishing a robust foundation in robotics education and application. Understanding VSC enables the customization of curriculum and allocation of resources to meet students' specific needs, effectively preparing them for careers in robotics and related fields. Consequently, this study aimed to compare VSC factors and their impact on opinions regarding RLD. Data were collected from vocational students in educational institutions under the Ministry of Education's school system for the year 2023, and analysed using both descriptive and inferential statistics. The study formulated six hypotheses to guide its investigation.

Among the study hypotheses, it was observed that gender does not exert a significant influence on RLD. This lack of significant association suggests that gender does not substantially impact RLD, challenging initial assumptions regarding gender-based perspectives in this domain. This finding aligns with previous research suggesting minimal gender differences in attitudes towards robotics once exposure and experience levels are considered (Su et al., 2023). Similarly, other studies have also indicated that gender has negligible effects on RLD across various educational contexts (Villalustre & Cueli, 2023). These results challenge assumptions about the significant gender-based impacts on RLD and underscore the importance of considering individual experiences and exposure levels in understanding attitudes towards robotics across genders. Furthermore, contrary to initial hypotheses proposing statistical differences, studies such as those by Alam (2022) and Chen et al. (2020) have found minimal effects of learning status among robotics systems on RLD outcomes once factors like exposure time and instructional methods are controlled. These findings suggest that enhancing human resources development also contributes to the enhancement of RLD. Regarding the vocational education teaching model that emphasizes promoting LEARN_STA to influence RLD, it aligns with the National Vocational Education Qualifications Standards Framework and Ministry of Education guidelines (Ministry of Education, 2023). Therefore, these results indicate that while various factors may influence RLD, specific learning statuses within robotics systems may not be determinative in shaping literacy development in this field. Understanding these relationships is crucial for refining educational strategies aimed at fostering robotics literacy across diverse learners.

The subsequent findings indicate that Learning Type about Robotic Systems (LEARN-TYPE) significantly influences RLD, confirming the hypothesis positing a statistical relationship between LEARN-TYPE and RLD. These results align with previous studies (Shakeshaft, 2023; Wich, 2022) that demonstrated individuals engaging in active learning experiences with robotic systems exhibited notably higher levels of robotics literacy compared to those who passively observed or received theoretical instruction alone. These studies underscore the pivotal role of active learning approaches in augmenting RLD, suggesting that educational strategies focusing on practical engagement with robotic systems can substantially enhance robotics literacy among learners. Moreover, the acquired learning can serve as a foundation for practical applications in specialized technical fields, particularly at the collegiate level. Additionally, other hypotheses reveal that Robot Learning Objectives (LEARN-OBJ) also exert a positive and significant impact on RLD. The findings align with previous research (Atman Uslu et al., 2023), which demonstrated that clearly defined learning objectives specific to robotics education, such as mastering programming languages or understanding robotic mechanics, significantly enhance RLD among learners. Thus, organizing teaching and learning processes, creating educational materials, developing faculty expertise, and implementing effective internships or vocational training align with curriculum objectives (Sapnirund, 2016). These empirical findings underscore the importance of structured learning objectives in shaping robotics literacy, emphasizing the efficacy of targeted educational strategies in fostering comprehensive understanding and skills in robotic systems.

The study reveals that the subject matter within robotic systems (LEARN-SUB) also exerts a positive and significant impact on RLD, confirming the hypothesis that different LEARN-SUB categories lead to varying perceptions of RLD. These findings are consistent with previous research by Ragusa and Leung (2023) and Wu and Li (2024), which underscored that exposure to diverse aspects of robotics shapes individuals' perceptions and competencies in this field. For example, learners focused on AI applications may develop distinct perspectives on RLD compared to those concentrating on mechanical aspects. These insights highlight the multidimensional nature of robotics literacy and underscore the importance of tailored educational approaches across various subjects within robotics to enhance comprehensive understanding and skills. Furthermore, the study indicates that the necessity of internships for utilizing robot-related jobs (INTERN-NEED) also significantly influences RLD positively. The findings suggest that engaging in internships enhances expertise necessary for qualified workforce development, thereby impacting RLD positively. This aligns with studies by Patiño-Escarcina et al. (2021) and Wu and Li (2024), supporting the notion that theoretical learning alone is insufficient for cultivating robust knowledge and skills, particularly in specialized domains (Barakina et al., 2021; Nghia & My Duyen, 2018; Patacsil & Tablatin, 2017) Such practical experiences enable students to understand objectives clearly and apply their knowledge effectively in real-world contexts, positioning them as valuable assets capable of contributing to organizational success (AlHamad et al., 2022). However, efforts related to INTERN-NEED necessitate ongoing support from both public and private sectors to enhance teaching and learning effectiveness and its impact on RLD. Therefore, educational institutions should prioritize the establishment of clear Robot Learning Objectives to bolster RLD.

5. Implications

5.1 Theoretical Implications

The study contributes theoretically to understanding RLD among vocational students. Initially, gender does not demonstrate a significant impact on RLD. These findings suggest that considering individual experiences and exposure levels is crucial, rather than relying solely on gender-based perspectives. Secondly, the study finds that Robotics System Learning Status has minimal influence on RLD when controlling for exposure and instructional methods, highlighting the complex factors influencing skill development in robotics. This finding contributes to cognitive load theory by suggesting that effective educational strategies, rather than previous experience alone, significantly shape robotics literacy. Moreover, the positive effects of Learning Type (LEARN-TYPE) and Robot Learning Objectives (LEARN-OBJ) on RLD underscore the importance of structured educational approaches. These results align with constructivist learning theories, emphasizing active learning methods and clear learning objectives to enhance comprehension and application of robotics knowledge. Therefore, the research extends the theoretical framework by illustrating how tailored educational pathways can enhance comprehensive problem-solving skills crucial in a globalized context.

5.2 Practical Implications

The study also contributes practically to educational experts and external industry stakeholders aiming to enhance literacy among students. Firstly, the research findings guide educational institutions in prioritizing active learning experiences (LEARN-TYPE) that promote hands-on engagement with robotic systems. Integrating practical projects and simulations into curricula enables educators to effectively foster technical skills and problem-solving abilities crucial for careers in robotics. Secondly, the emphasis on clear Robot Learning Objectives (LEARN-OBJ) underscores the importance of aligning curricula with industry standards and emerging technologies. This practical approach ensures that vocational education programs equip students with the relevant competencies demanded by the labour market. Lastly, the study highlights the significant role of INTERN-NEED in bridging theoretical knowledge with practical application. Collaborations between educational institutions and industry partners provide students with valuable hands-on experiences, enhancing their readiness for professional roles and contributing to their proficiency in robotics systems.

6. Limitations and Future Research

The study has identified several limitations that could be addressed in future research to enhance the generalizability of findings. Firstly, this study primarily focuses on students' perspectives regarding RLD within the context of vocational education, positioning them as outputs of the human resource development process at the college level. While valuable, the research overlooks perspectives from other stakeholders such as college personnel, employers of students, parents, universities or institutions accepting students for further education, unemployed individuals, and others. Future research should aim to include these stakeholders to gather comprehensive data necessary for informed policy development. Furthermore, the study's scope is restricted to technical and robotics education, aimed at cultivating essential 21st-century skills. While this focus is pertinent, it limits the breadth of research. Future studies could broaden the scope to include other sectors or disciplines, thereby enhancing the diversity of research findings. Moreover, the study employs a quantitative deductive approach, which, while suitable for its objectives, restricts exploration into qualitative dimensions. Future research could explore mixed methods approaches, integrating qualitative insights alongside quantitative data. This methodological diversification could enrich understanding and enhance the generalizability of research outcomes. In summary, addressing these limitations in future research endeavours could provide a more comprehensive understanding of RLD, encompassing broader stakeholder perspectives, expanding sectoral coverage, and employing mixed methods approaches for a more nuanced exploration.

7. Conclusion

The study aimed to assess how vocational/college student characteristics influence robotics literacy development among individuals with a vocational education background. Using both descriptive and inferential statistical analyses, the study examined various hypotheses concerning the impact of factors such as gender, robotics system learning status, learning methods, robot learning objectives, emphasis on specific robotics subjects, and the importance of internships on RLD. The results indicate that gender and robotics system learning status do not significantly affect RLD. In contrast, active learning experiences (LEARN-TYPE) and clearly defined robot learning objectives (LEARN-OBJ) positively influence RLD. Additionally, the study underscores the significance of subject-specific learning (LEARN-SUB) and the crucial role of internships (INTERN-NEED) in connecting theoretical knowledge with practical application, thereby enhancing robotics literacy among vocational students. Moreover, the findings provide practical implications for educational institutions to refine curricula, prioritize experiential learning, and strengthen industry collaborations, thereby better preparing vocational students for dynamic careers in robotics and related fields.

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