Advancing Technical Education at IFAM: Real-World Application and Impact of LoRaWAN Integration on Developing Future-Ready Skills

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***Abstract*—Rapid technological evolution and the advent of the Internet of Things (IoT) are reshaping the necessary competencies for professionals in different fields, including engineering that focuses on networking, telecommunications, IoT, or embedded systems. This research project proposes an in-depth analysis of the benefits brought about by the inclusion of LoRaWAN technology in the curriculum of courses offered by the Instituto Federal do Amazonas (IFAM), focusing on both technical skills (hard skills) and interpersonal and cognitive competencies (soft skills) of students participating in research, development and innovation project (R,D&I). LoRaWAN, a low power long-range communication technology, has significant potential for applications in smart cities, precision agriculture, natural resource management, and smart power meters, underscoring its relevance to current and technical education. LoRaWAN technology integrates various engineering disciplines in the curriculum, challenging the update process. The paper suggests a method to assess the performance of 12 students in three R, D, I projects for the improvement of the curriculum. Identifies the impact on students' education and provides guidance for educational institutions based on students' task difficulties and interaction with the development team.**

***Index Terms*—Curriculum, LoRaWAN technology, real project**

I. Introduction

A significant challenge for technology-based educational institutions is the ongoing evolution of technology, which requires frequent curriculum updates. The Instituto Federal do Amazonas (IFAM) faces similar challenges in its technical and engineering courses. While current data network curricula emphasize the 802.11 standard and its applications, this standard does not adequately address the specific challenges posed by Internet of Things (IoT) applications. Although the 802.11 standard facilitates higher data volumes, it is limited by shorter transmission distances. In contrast, LoRa technology is designed for low data transmission over long distances with minimal energy use, which is crucial for IoT devices. Consequently, this article aims to explore the LoRaWAN technology and its challenges to better align the academic curriculum with current technological knowledge and industry needs.

The emergence of IoT technologies has initiated a new era of digital transformation, with LoRaWAN emerging as a notable technology due to its approach to addressing challenges faced by traditional cellular networks. LoRaWAN devices are designed for minimal energy consumption, making them suitable for remote or difficult to reach areas, ensuring long-lasting and sustainable IoT solutions [1]. This technology blends computer science, engineering, and data science, promoting the development of varied skill sets crucial in today's interconnected tech landscape.

LoRaWAN technology blends computer science, engineering, and data science for a holistic educational approach. Promotes the development of a varied skill set crucial in today's interconnected tech landscape. Technology encompasses both hardware and software aspects, such as printed circuit board design, embedded system projects, network design, data security, device management, and data analytics necessary for IoT network deployment and upkeep.

Practical experience improves the job prospects of students through hands-on learning. Active teaching methodologies such as project-based learning (PBL), design thinking (DT), and challenge-based learning (CBL) improve students' skills [2]. However, these methodologies may not fully prepare students for the entire project life cycle, particularly in developing innovative products with high Technology Readiness Levels (TRL 6-9).

The importance of understanding the gaps in the curricular teaching of technology and engineering skills for future professionals in IoT and soft skills was noted at IFAM, prompting this research effort to pinpoint effective actions to enhance the preparation of prospective professionals. A curriculum study to identify skills learned in each discipline is crucial for this purpose. By training students in LoRaWAN, educational institutions can directly address the skills gap in the workforce, preparing students to contribute effectively to these sectors upon graduation.

The article discusses background related to updating the computer science curriculum and identifying good practices. Methodology proposes mapping skills from R&D projects to IFAM courses. The case study reviews three projects in telecommunications technology and system automation, highlighting areas for improvement. Conclusion summarizes results and suggests future work.

In addition, soft skills can be effectively incorporated into academic projects to simulate real-world scenarios. The Soft Skills Framework (SSF) serves as an appropriate model for this purpose. Originally from the Soft Skills Matrix, an initiative by SENAI [3], SSF was influenced by the key competencies highlighted in The Future of Jobs Report 2018 by the World Economic Forum [4], which are essential in the context of Industry 4.0's new technologies. SSF comprises five main components: i) critical thinking and innovation; ii) entrepreneurship; iii) complex problem solving; iv) emotional intelligence; v) leadership and social influence. These components are crucial in improving the student's abilities and are frequently employed in R,D&I projects [5].

According to the World Economic Forum [6], the ten main skills for work-life in 2022 are: Analytical thinking and innovation; Active learning and learning strategies; Creativity, originality, and initiative; Technology design and programming; Critical thinking and analysis; Complex problem-solving; Leadership and social influence; Emotional intelligence; Reasoning, problem solving and ideation; Systems analysis and evaluation.

Thus, its relevance recognized the necessity to improve understanding of hard and soft skills in relation to IoT LoRaWAN projects, particularly to evaluate gaps in teachers' academic training for technological project development.

II. BACKGROUND

The synergy between academia and industry is crucial to advancing technology-based curricula [7], equipping future professionals for R, D&I project. The evolving technology landscape requires teacher revisions of the curriculum to prepare students for future careers and improve their abilities. Employing active methodologies in classrooms enhances students' hard and soft skills through academic projects. An R,D&I team can drive innovation by translating ideas into products, services, or processes. The team can collaborate with experts from various disciplines to build a culture of innovation and conduct research on emerging technologies and market trends. Academia and industry can also work together to bridge the gap between research and commercial application [8].

Different studies contribute to the academic community by demonstrating the application of simulation technology in learning telecommunication networks, which is crucial to understanding the complexities of IoT systems [1], [9], [10]. The prevalent idea is often shared about how using special computer programs to mimic the way devices connected to the IoT work can help students learn better about telecommunication networks with experiences using simulation tools for IoT works, which helps in teaching and training future engineers more effectively by providing them with practical, real-world-like scenarios.

Focusing on the rapid development of IoT and its diverse applications, [9] encourages universities worldwide to integrate IoT courses into their curriculum, thus preparing students for technological advancements in their future careers. It highlights the importance of integrating IoT technology into university curriculums, thereby preparing students for the rapidly evolving field of telecommunications through hands-on learning experiences. The approach focuses on a virtual environment using simulator tools. The development of IoT hardware is not considered.

A study was conducted on the adoption of cutting edge IoT technologies within the Computer Science curriculum at Prairie View A&M University, which can be seamlessly incorporated into existing CS courses to stimulate student participation in smart-IoT [10]. The inclusion of IoT educational modules into the curriculum has demonstrated beneficial effects on students' enthusiasm and comprehension of IoT frameworks. This initiative aims to provide students with the necessary competencies to understand and develop IoT applications, covering fundamental principles of IoT, crucial components of the IoT ecosystem, its applications, trends, consequences, and hands-on lab activities involving sensor and actuator networks, along with cloud data processing. These are vital for crafting real-world IoT applications. Students acquire skills in handling both IoT hardware and software, including the use of ready-made components and grasping distributed and parallel computing principles. The significance of minimal power and memory usage in IoT systems is highlighted, equipping students to address design challenges in the design of efficient IoT solutions. However, participating in these projects uncovers challenges that require better problem-solving skills.

A study conducted at Nankai University via industrial collaboration analyzed the necessity and feasibility of introducing the IoT course as a general elective course for undergraduates and proposed a curriculum that adopts the Niagara framework as a laboratory platform. The goals are to make experiences using simulation tools to teach the functioning of the IoT network and facilitate the training of future engineers. The authors presented a study showing students' interest in IoT technology and the improvement of technical skills in communication networks and practical applications in the laboratory [11].

Technological R&D,I projects demand the implementation of strategic planning, effective management, and team organization methodologies to execute a series of interconnected activities and assignments that require the involvement of people with soft and hard skills, which are crucial for cultivating the capabilities of prospective engineers and researchers. Examining the project can reveal gaps in student training and the necessary laboratory structure. This can bridge the gap between academia and industry, guiding curriculum updates, and highlighting the importance of teacher training. It also motivates teachers and students to tackle real-world challenges beyond traditional laboratory settings, which may not fully prepare them for industrial environments.

III. METHODOLOGY

The methodology is based on the experiences of teachers and researchers in managing LoRaWAN projects. The good practices of the PMBOK guide [12] and the international standards ISO/IEC/IEEE 15288:2008 [13] and ISO 12207:2009 [14] were used to support the planning and management of the essential Work breakdown structure(WBS) [15] for the system life cycle process.

Therefore, six crucial steps were outlined, encompassing phases of the project which served as input to assess the hard and soft skills required to support future LoRaWAN technology developers. Consequently, they offer assistance in examining the curriculum framework and its influence on teachers and students. Figure 1 illustrates the six steps outlined in the methodology, beginning with the participation of the factory and stakeholders, including industry specialists facing challenges. The process extends to improving teachers' skills to address technological advancements and ensuring quality training for students.

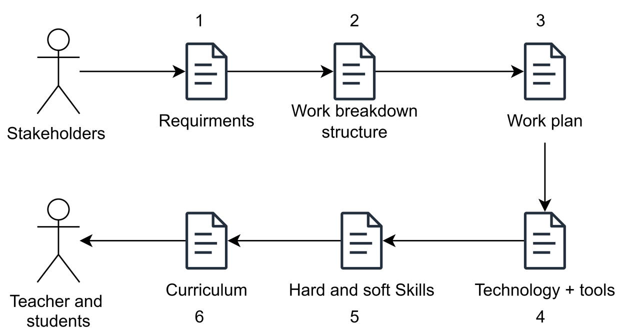

Fig. 1: Methodology proposed

A. STEP 1: Requirements document

In this step, the purpose of the project and the document are defined to help stakeholders understand it. List all involved parties, including end users, project managers, developers, and clients. Collect detailed requirements from stakeholders through meetings, interviews, or surveys. Organize requirements into functional, nonfunctional, and interface categories. Describe each requirement and prioritize according to importance and impact. This document serves as a foundational basis for describing the specifics of the project team, including developers, technologies, and tools. It also helps to determine the necessary skills that team members must have by analyzing the requirement document.

B. STEP 2: Work breakdown structure

Through the requirements elicited by the client, the commencement of WBS development begins, which simplifies intricate projects through the decomposition into feasible tasks. This process facilitates resource allocation, and the delineation of the domains of proficiency necessary to form the developer group focuses on identifying areas and skills.

C. STEP 3: Workplan analysis

The work plan includes the WBS and details on programs, equipment, human resources, laboratory structure, and team member profiles. It also outlines activities and tasks for project planning and management. Document analysis is crucial to recognize the hierarchy of human resources. Teachers, students, and specialists collaborate to bridge the technological knowledge gap between academia and industry. Researchers can use this document to identify project technologies and tools.

D. STEP 4: Technology + tools analysis

In this crucial step, the project coordinator and manager collaborate to determine the students' macro profile based on the technological requirements of the project. They systematically extract and categorize the hard skills necessary for successful project execution, focusing on LoRaWAN-specific technologies and associated tools.

Initially, a detailed mapping of project technologies is conducted, encompassing LoRaWAN-specific hardware and software components, followed by the identification of requisite tools for development, testing, and deployment. Based on this information, a skills matrix is developed, correlating technologies and tools with required competencies, establishing clearly defined proficiency levels. This multifaceted process not only guides the selection and allocation of students to specific project roles but also informs the development of targeted training programs.

E. STEP 5: Hard and soft skills analysis

The coordinator assigns small tasks to students with deadlines, monitors progress using agile methodology, for example, and identifies challenging knowledge for additional training. Successful tasks show commitment to the mission and evaluate whether fundamentals were learned through the course or self-teaching in the next step. A series of questionnaires were created for students to evaluate their performance in the project life cycle. The questionnaires aim to pinpoint students' skills and determine how they acquired their knowledge, classroom or self-taught.

IoT application development requires specific skills, knowledge of hardware and firmware may be needed depending on expertise. Low energy consumption is crucial in IoT devices due to their installation in areas with a low power supply. Hardware designs with low-power characteristics require careful component selection for evaluating energy consumption and maintaining necessary functionalities.

Students should learn CAD tools for hardware development, especially for creating Printed Circuit Boards (PCB). Developing PCBs for IoT devices with wireless communication requires understanding of RF issues such as impedance characteristics, antennas, and shielding. Manufacturing PCBs for IoT devices involves knowledge of RF parameters related to materials, plate thickness, and dielectric used.

Students must understand various interfaces and communication protocols for IoT devices such as WiFi, LoRA /

LoRaWAN, NB-IoT, and BLE. This knowledge aids in hardware and firmware development by guiding the design of the physical layer and the selection of the necessary APIs. Firmware development for IoT devices demands knowledge of Embedded Systems, especially in managing different operating modes of microcontrollers for energy efficiency and performance.

Students must grasp the hardware and firmware project development flow, from specifying requirements to creating detailed development schedules. Additionally, proficiency in English writing and reading is essential for the generation of technical reports during the development process.

F. STEP 6: Data Collection and Analysis

We collected data on student performance through weekly task assessments and bi-monthly surveys. Weekly evaluations tracked progress on assigned tasks and evaluated hard skills related to LoRaWAN technology. The bimonthly surveys used the SSF to assess five key components: critical thinking and innovation, entrepreneurship, complex problem solving, emotional intelligence, and leadership and social influence. Students rated their abilities on a scale of 1 to 5 for each component. We analyze these data to identify trends in skill development and areas that need improvement.

For data analysis, we employed a mixed-methods approach, combining quantitative and qualitative techniques. We used descriptive statistics, including measures of central tendency (mean, median) and dispersion (standard deviation, range), to summarize the quantitative data from the SSF surveys and task performance scores. To assess significant changes in soft skills over time, we performed paired t tests comparing initial and final SSF scores for each component.

G. STEP 7: Curriculum analysis

In this step, based on the outcomes of the surveys that gather data on the acquisition of hard and soft skills, an examination is conducted to establish a connection between the obstacles faced during the execution of assigned tasks by students and the subjects within the curriculum, along with the adequacy of the teacher's qualifications. Consequently, a report is compiled by the curriculum evaluation team that highlights courses that require revision to align with the core principles of technology, which include specialized / technical aspects and the enhancement of interpersonal skills and initiatives. The analysis performed in Step 4 may propose a basic laboratory setup.

IV. STUDY CASE

The case study is a collaborative effort between the Inova hub and its industrial partners to launch research projects to promote innovation and maintain a competitive edge. The Innova Hub in Amazonas is associated with IFAM and is committed to promoting advanced technological education, extension activities, and applied research tailored to industries with students, professors, and experts. The partnership focuses on integrating LoRaWAN technology into educational curricula to create a unique context for students to learn.

Three LoRaWAN technology projects have been conducted, involving 36 individuals, including educators, experts, and IFAM students from various engineering and technology courses. Each project was managed by supervised technical instructors with experience in project management and LoRaWAN technology. The involvement of external specialists plays a crucial role in bridging technology with academic settings.

The proposed approach was applied to projects with requirements documents, WBS, and a work plan that describes the technologies and tools used. Applying ***Step 1*** we analyze the project requirements by studying the documents, identifying pain points, structuring requirements by area and involving the students in internal meetings to understand the nuances of the project and the expected results. Students also assist developers with documentation tasks and proposal validation with stakeholders. At this time, students were assessed using a questionnaire to measure their ability to take initiative to understand the company's needs, proactivity, systematically arranging the information using a structured tabulation of the criteria based on different macro-areas defined by ***Step 2*** in which students grasp the magnitude of the project, the makeup of the teams, the goals, and the coordination where an unfinished task could pose risks to the project's advancement.

The examination of the work plan, ***Step 3 - Work plan analysis***, aims to determine the allocation of activities and tasks to students based on the delineation of teams per specific area as outlined in the Work Breakdown Structure (WBS). Students are assigned tasks according to their original competencies within the project and their interest in the subject matter that stems from previous experiences. The delegation of tasks to students is decided by the coordinator, who will oversee the students' progress by evaluating their delivery and conduct. The definition of activities is linked with technologies and tools, specifically ***Step 4 - Techonolgy and tools***, determined by teams when creating the WBS and the work plan. Thus, students must be in sync with their team members.

During the project development, the coordinator supervises and assigns new tasks every week. The task assessments of the previous week aim to evaluate student capabilities by tracking their progress in tasks, as outlined in ***Step 5 - Hard and soft skills***. Weekly, students report their findings according to agile project principles, discussing their achievements, obstacles, and results. Every two months, students complete a survey detailing the challenges encountered, the solutions discovered and their insights into classroom teaching.

At this stage, the coordinator records in an additional document the complexity level of the task, the technologies and tools involved, the challenges faced, and the strategies employed by the student to resolve these issues. Figure 2 shows an example of the hard skills mapping used.

The SSF approach was used to assess student soft skills every two months using a questionnaire with scores ranging from 1 to 5, indicating varying levels of capacity. Figure 3

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Project name: LoRaWAN Tracksystem

Coordinator: Diego C. Sales

Date: 05/20/2024 – 05/27/2024 Weak work: 05/100

Team: PCB development Activity: Create PCB model

Task: Create a source power system

Technology and tools: PCB development with Altium designer tool

Student name: João dos Santos

Results: 10% from 100%.

Identified issues: The student struggled with using the tool and concepts for designing a printed circuit board based on the provided architecture definition. The difficulty arose from the program's English language and unaddressed technical terms. The student turned to YouTube and online training for help, but he needed more time to fully understand and execute the task.

Fig. 2: Report student sprint

shows the input and output data from two assessments, with the input representing the results of the previous assessment and the output representing the current assessment for each student.

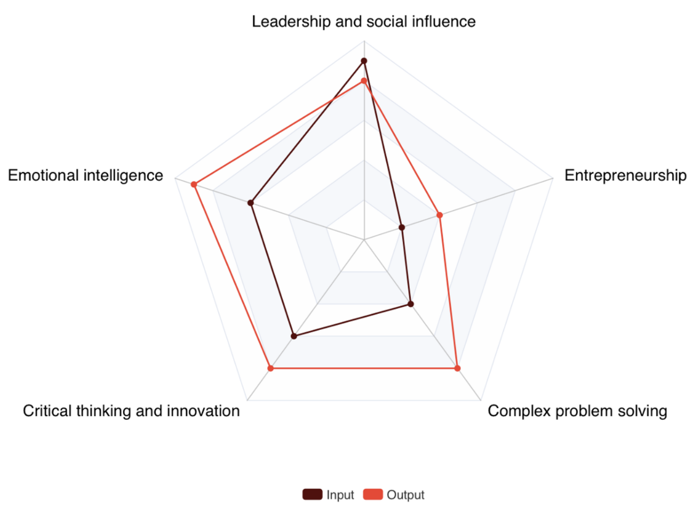

Fig. 3: Example of one student Soft skills results

Six bimonthly evaluations and 48 weekly evaluations will be conducted using the SSF questionnaire. The results will be analyzed in a future study. These projects are in the final phase to evaluate the students' abilities from start to finish.

In the future, an analysis will be performed on the curriculum base presented in Step 7 to identify the gaps and minimum laboratory structure needed to integrate LoRaWAN technology and the fundamentals of IoT.

V. Conclusion

This study evaluates the hard and soft skills of students who participate in three LoRaWAN technology R,D&I projects. Analysis of the work plan and task assignments has revealed significant knowledge gaps among students, which hinders project execution and technology comprehension. These challenges underscore the need for students to enhance their emotional intelligence, critical thinking, and self-directed learning abilities to adapt to ongoing technological advancements.

In future work, we plan to conduct a comparative analysis between students who have participated in these LoRaWAN projects and those who have not taken specific IoT or LoRaWAN courses. This comparison will help us quantify the impact of these real-world projects on skill development and identify areas where traditional coursework may need to be supplemented or modified.

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References

[1] J. Haxhibeqiri, E. De Poorter, I. Moerman, and J. Hoebeke, "A survey of lorawan for iot: From technology to application," *Sensors*, vol. 18, no. 11, p. 3995, 2018.

[2] V. Sukackė, A. O. P. d. C. Guerra, D. Ellinger, V. Carlos, S. Petronienė, L. Gaižiūnienė, S. Blanch, A. Marbà-Tallada, and A. Brose, "Towards active evidence-based learning in engineering education: a systematic literature review of pbl, pjbl, and cbl," *Sustainability*, vol. 14, no. 21, p. 13955, 2022.

[3] J. d. R. Penhaki *et al.*, "Soft skills na indústria 4.0," Master's thesis, Universidade Tecnológica Federal do Paraná, 2019.

[4] T. A. Leopold, V. S. Ratcheva, and S. Zahidi, "The future of jobs report 2018," in *World Economic Forum*, vol. 2, 2018.

[5] D. C. Sales, G. M. Breves, J. P. Neto, and C. Figueira, "Integrating active methodologies in the r, d&i projects to improve student's skills: A case study," in *2023 IEEE Frontiers in Education Conference (FIE)*. IEEE, 2023, pp. 1–9.

[6] K. Schwab, "Insight report: The future of jobs report," in *World Economic Forum. https://doi. org/10.1177/0891242417690604*, vol. 10, no. 0891242417690604, 2018.

[7] P.-A. Quezada-Sarmiento, L.-E. Enciso-Quispe, J. Garbajosa, and H. Washizaki, "Curricular design based in bodies of knowledge: Engineering education for the innovation and the industry," in *2016 SAI Computing Conference (SAI)*. IEEE, 2016, pp. 843–849.

[8] E. Sengupta, P. Blessinger, and N. Nezaami, "Introduction to governance and management in higher education," in *Governance and Management in Higher Education*. Emerald Publishing Limited, 2022, vol. 43, pp. 3–11.

[9] M. L. Mouronte-López, Á. Lambertt Lobaina, E. Guevara-Martínez, and J. A. Rodríguez Rubio, "Design and simulation of an iot intelligent university campus for academic aim," in *International Conference on Human-Computer Interaction*. Springer, 2023, pp. 64–78.

[10] A. A. Ahmed, K. Bellam, Y. Yang, and M. Preuss, "Integrating iot technologies into the cs curriculum at pvamu: A case study," *Education Sciences*, vol. 12, no. 11, p. 840, 2022.

[11] Y. Guo and M. Li, "Iot course construction in general education against the background of china's university-industry collaboration," in *2022 4th International Conference on Computer Science and Technologies in Education (CSTE)*. IEEE, 2022, pp. 128–132.

[12] A. Guide, "Project management body of knowledge (pmbok® guide)," in *Project Management Institute*, vol. 11, 2001, pp. 7–8.

[13] I. Standard, "Systems and software engineering–system life cycle processes," *ISO Standard*, vol. 15288, p. 2008, 2008.

[14] I. ISO, "Iec 12207 systems and software engineering-software life cycle processes," *International Organization for Standardization: Geneva*, 2008.

[15] T. R. Devi and V. S. Reddy, "Work breakdown structure of the project," *Int J Eng Res Appl*, vol. 2, no. 2, pp. 683–686, 2012.