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Fostering Electronic Engineering Students' Problem-Framing Skills in a Client-Based Project

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Abstract–Problem-framing skills are central to engineering design, yet traditional engineering curricula often emphasize well-structured, algorithmic problems that limit students' engagement in problem framing. Client-based projects offer a promising means of creating authentic design experiences that support students' problem framing skills, but their effective implementation in engineering courses represents several pedagogical and logistical challenges. Consequently, this study asks: How might a client-based project promote students' problem-framing skills in a fourth-year electronic engineering design course? Using a design-based research approach, we examined an iteration of a redesigned electronic design course that integrated a client-based project. Data included student team artifacts, video-recorded client–student interactions, and interviews with students, the client, and the instructor. Findings indicate that students were able to translate client needs into design requirements while meeting course learning outcomes, and that engagement with multiple stakeholders supported deeper evaluation of solutions and richer understanding of the problem space.

Keywords-- Problem-framing, electronic engineering, design-based research, undergraduate students.

I. Introduction

Although engineering design is widely recognized as a fundamental engineering practice, undergraduate engineering curricula still tend to emphasize analysis and algorithmic problem solving, limiting students' opportunities to develop design skills [1], [2], [3]. Unlike algorithmic problems, engineering design problems are ill-defined and require designers to actively frame them by identifying client needs, negotiating among stakeholders, and proposing and validating requirements—a process known as problem framing [4], [5]. One approach to foster students' problem-framing skills is the use of client-based projects in the classroom that engage students with authentic design experiences. However, collaborating with real clients in engineering courses presents significant challenges [6], [7], and it remains unclear how such projects can be effectively implemented to support students' design skills, particularly problem framing. We restructured a fourth-year electronic design class to better support students' development of problem-framing skills by integrating an authentic client-based project. In this study, we explored the students' problem-framing skills when participating in the new version of the course. Particularly, we ask:

How might a client-based project promote students' problem-framing skills in a fourth-year electronic engineering design course?

II. Literature Review and Theoretical Framework

Engineering design is a central, distinctive practice in engineering [8]. The accrediting program, ABET, includes design among its student outcomes, expecting that professional engineers are able to "apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare as well as global, cultural, social, environmental, and economic factors" [9]. However, as both instructors and students attest, both teaching and learning engineering design are not easy.

Traditional engineering education prioritizes an engineering science stance in which students are predominantly required to solve complex and well-structured problems through model-based reasoning and applying mathematics and science concepts [1], [2], [3]. But, engineering design problems are ill-structured in nature, meaning that these problems do not have a single correct answer like homework and problem sets. Ill-structured problems can be solved in different, satisficing ways [10].

Designers address ill-structured problems through an iterative process of problem framing, solution generation, and solution evaluation until finding a satisfactory solution [11]. Previous researchers have theorized this process as the iterative exploration of the problem space and the solution space [12], [13], [14]. For example, consider the development of a new system or product to mitigate the impact of urban flooding. In that context, the problem space includes the characteristics and needs of stakeholders (e.g., citizens, the mayor, environmentalist groups, etc.) and constraints and requirements of the problem (budget, geography of the area, climate patterns, etc.). The solution space is formed by possible solutions to the problem, such as improving building structures, construction of channels, planting green areas to capture water, etc. Designers analyze aspects and entities from both the problem and solution spaces, and as they gather more information, they anticipate possible outcomes [15].

While the analysis, synthesis, and evaluation of possible solutions have been a priority in engineering courses, engineering design also demands that students be capable of exploring the problem space, a process called problem framing [4], [5]. While engineering students learn throughout their undergraduate courses to analyze technological solutions that address problems provided to them; to synthesize new technologies based on their research and models; and to evaluate the effectiveness of a technology to solve a given problem, they have comparatively few opportunities to frame engineering problems [1].

A. Problem-Framing Skills in Engineering Design

Expert designers engage in several practices to frame design problems. For this work, we focus on three aspects of problem framing that have been reported as highly relevant in undergraduate education [16], [17]. These aspects are tied to the notion of determinedness [18]: In a design problem, there are aspects of the problem that are categorized as determined, meaning they are known or uncoverable, and this often includes information about the problem context, stakeholders, their needs, the situation, and the constraints it presents. Next, some aspects of design problems are underdetermined, meaning they can only be determined through specific engineering practices of staying tentative and iterating. Finally, some aspects of design problems are undetermined, meaning they are subjective and decided based on preference and experience. We detail each of these.

Defining needs, constraints, and requirements. Expert designers identify needs and constraints initially based on the design problem [19]. They consider contextual characteristics, gather information to have a broader perspective of the problem, seek out varied stakeholders' perspectives and needs, and explore existing solutions and available resources [20]. Based on the designers' understanding, they formulate requirements as a design promise for the client [21].

Staying tentative and iterating between problem and solution spaces. Addressing a design problem is an iterative process of exploring the problem and solution spaces [12], [13], [14]. Consequently, designers do not rely only on their initial understanding of the problem but stay open to new insights throughout the design process. Namely, when analyzing and evaluating possible solutions, they stay open to insights about the problem, which in turn can result in a reframed problem or a refined understanding of the problem (e.g., a new constraint). And because problems and solutions co-evolve, the very solution that helped them notice something new about the problem may, as a result, become inadequate for solving this refined problem. This co-evolution process requires designers to stay tentative throughout the design process and avoid early commitments to solutions.

Using preferences and prior experience. The undetermined aspects of design problems cannot be addressed by inductive or deductive processes; instead, designers frame the problem using their preferences and judgements built from prior experiences, abductively [12].

Collectively, these three components of problem framing demand that designers have adequate agency to make consequential decisions—termed framing agency [22], [23]. Having this kind of agency is critical for directing problem framing actively. Yet, this agency is not like free will, nor is it, as has classically been depicted, a dialectic between enduring structures and individual human choices [24]. Rather, designers' agency is shared with the problem context, stakeholders, and the very materials with which they work [25].

B. Authenticity and Client-Based Projects to Support Problem-Framing Skills

Integrating authentic engineering problems in the classroom has been shown to provide opportunities for students' development of problem-framing skills [17]. Authentic problems are not conceived for teaching; instead, they present ill-structured, real-world needs or tasks [26]. For example, client-based projects are based on addressing authentic problems that allow students to develop higher-order thinking, foster agency, and allow them to develop professional skills [27]. However, inviting real clients to classroom projects has several challenges such as spending more time in class preparation, planning spaces for students-client interactions, foster healthy competition between students among others issues [6], [7].

Although authentic problems are ill-structured in nature, instructors tend to simplify them for the students, minimizing their opportunities to develop problem-framing skills. For example, when designing a system to mitigate urban flooding, an instructor may reduce the problem's ill-structuredness by excluding political considerations related to infrastructure development or may directly frame the problem for the students by asking them to focus only on evaluating the technical feasibility of changing the road traditional asphalt for a new permeable one. In the last case, the instructor would have framed the problem by providing a specific solution (i.e., permeable asphalt), and the students would focus on problem-solving skills by investigating types of asphalt, analyzing physical-chemical properties, calculating costs, etc. Although those tasks support students developing technical and analytical skills, we argue that students also need to develop problem-framing skills.

III. Methodology

This study followed a design-based research (DBR) approach, a methodology rooted in the learning sciences that supports the iterative design and study of learning environments while simultaneously testing theoretical conjectures in real-world contexts [28]. DBR was selected because it allows for the investigation of learning processes within the authentic complexity of an engineering classroom. Specifically, we conjectured that scaffolding the students' design process when working on a client-based that included determined, underdetermined, and undetermined components might promote the development of students' problem-framing skills. This was the basis for restructuring the electronic design course, shifting from a project focused on technical problem solving to one that also supported problem framing. The current paper presents the first iteration of the new course structure. We explored this iteration taking a qualitative constructivist stance [29] to better understand the students' experience in the new learning environment.

A. Setting and Course Structure

The study was conducted in Electronic Design, a fourth-year undergraduate course in the Electronic Engineering program at a private university in Barranquilla, Colombia. The course is positioned as a capstone-like design experience, aimed at integrating students' prior knowledge in electronics, telecommunications, and embedded systems through the structured development of a real-world engineering system.

The course is designed to support the development of both technical and professional competencies associated with engineering design. By the end of the semester, students are expected to be able to design and implement a functional electronic system for data acquisition and management under realistic constraints of scope, cost, and time. Additionally, students are required to justify design decisions using technical criteria, including the selection of technologies, communication protocols, and system architectures, supported by experimental evidence and comparative analysis. The course also emphasizes effective teamwork within an agile development framework, where students plan tasks, assume technical roles, monitor progress through weekly sprints, and address conflicts constructively. Finally, students are expected to communicate and defend their design solutions through formal presentations and functional demonstrations, articulating how their systems meet stated requirements and stakeholder needs. Together, these learning outcomes position the course as an integrative design experience that mirrors professional engineering practice.

B. The Macro Design Challenge

The course is explicitly designed as an active learning environment that combines Project-Based Learning (PBL) and Team-Based Learning (TBL) within an agile development framework [30], [31], [32]. Rather than organizing instruction around isolated technical topics, the course revolves around a single macro design challenge: <u>the design and implementation of a vehicular telemetry system</u>. This challenge provides a coherent technical narrative that spans the entire semester and allows students to experience the full lifecycle of an engineering design process under realistic constraints.

Students work in teams of up to four members and adopt defined technical and coordination roles. The development process follows a Scrum-inspired agile workflow, characterized by weekly sprints, incremental deliverables, and continuous formative feedback. Specifically, the course lasts three hours per week. Two hours per week are devoted to sprint sessions during which student teams report progress, demonstrate partial functionality, and receive formative feedback from the instructor. The remaining one hour is dedicated to focused theoretical reinforcement, where the instructor analyzes recurring technical challenges observed during the sprints, reflects with students on the outcomes of the previous deliverable from a project management perspective, and academically and technically frames the upcoming challenge.

The design challenge focused on the development of an IoT-based vehicular telemetry system, designed to acquire, transmit, store, and visualize georeferenced data from a moving vehicle. The technical scope of the macro design challenge was structured across three sequential projects:

- *Project 1* emphasized initial problem exploration and infrastructure setup. Students developed a basic mobile application capable of acquiring geographic coordinates and transmitting data using network communication protocols. This phase prioritized understanding data acquisition, communication constraints, and transport-layer protocol selection.
- *Project 2* extended the system to a cloud-based infrastructure. Students migrated their solution to cloud services, implemented a database, and developed a dynamic web interface capable of visualizing real-time and historical vehicle trajectories. This phase reinforced system integration and introduced considerations related to scalability, reliability, and user interaction.
- *Project 3* challenged teams to integrate automatic data acquisition mechanisms and propose student-defined system requirements. Students designed a more autonomous solution, often incorporating embedded hardware or vehicle interfaces, and refined data visualization to support decision-making

C. Evolution of the Design Challenge and Client-Based Project

During the semester reported in this study, the macro design challenge was reconfigured to integrate a client-based project. At the beginning of the semester, representatives from a Colombian Port presented an authentic operational problem related to vehicle tracking within port facilities. Rather than receiving a fixed technical task, student teams were required to interpret the client's expressed needs and propose design solutions accordingly.

The new structure transformed the project from a uniform, technology-driven assignment into an open-ended design problem grounded in a real-world context. Table I shows the new configuration of the course. While a macro design challenge was still split into three small projects, there were additional activities added to engage students with the client. Specifically, the Port Representatives presented their needs and constraints to the students at the beginning of the semester. Then, by the end of Project 2, some Port stakeholders came to the class to hear and validate the preliminary prototypes of the students. Finally, by the end of project 3, the stakeholders came again to evaluate the final prototypes and proposals. Furthermore, Project 3 was also intentionally redesigned to grant teams greater responsibility in structuring their work. Namely, the students could choose between carrying out the standard Project 3 goals summarized in Table I or proposing its own set of sprint deliverables based on their interpretation of the client's needs and their evolving system design. These proposed sprint plans were reviewed and approved by the instructor immediately before the start of Project 3, establishing a negotiated design space that balanced student autonomy with instructional oversight.

TABLE I
NEW STRUCTURE OF THE COURSE INTEGRATING A CLIENT-BASED PROJECT

Project	Sprint	Main Objective
Project 1 GPS Data Acquisition and Transmission	P1–S1	*Identify the problem and needs defined by the client* [a]. Develop a native Android application capable of sending geographic coordinates via SMS.
	P1–S2	Enable redundant transmission of GPS data to two external IP addresses and capture network traffic.
	P1–S3	Analyze and justify the selection of TCP or UDP based on captured traffic.
	P1–S4 Project 1 Deliverable	Deploy local web servers and store transmitted data in a database for real-time visualization.
		Validate end-to-end data transmission and protocol selection.
Project 2 Web Platform Development	P2–S1	Migrate system infrastructure to the cloud and integrate real-time map visualization.
	P2–S2	Implement collaborative version control and real-time trajectory plotting.
	P2–S3	Enable historical trajectory queries based on time windows.
	P2–S4 Project 2 Deliverable	Define product identity and validate usability with external users.
		Present partial project progress to the client. Demonstrate a functional cloud-based telemetry web platform.
Project 3 Automated Data Acquisition or Teams Proposed Project	*Intro P3*	*Reflect on customer needs and planning P3 Structure.*
	P3–S1	*Implement automatic data generation and location-based historical queries.*
	P3–S2	*Adapt the database to support automated data acquisition and hardware integration.*
	P3–S3	*Ensure web-based georeferenced visualization of acquired data.*
	P3–S4	*Display simultaneous tracking of two vehicles.*
	P3–S5 Final Deliverable	*Justify the selected transport protocol for the complete system.* *Present final prototype to the client.*

[a] Italics indicates changes to the structure of the design challenge to integrate a real client project.

D. Participants

Following approval by the University Ethics Committee, 27 students consented to participate in the study, divided into two sections: Section 1 with 14 students (11 males and 3 females), and Section 2 with of 13 male students. All of them were in their eighth semester at the University, were younger than 24 years old, and had minimum working experience.

The selection criteria focused on students who were not involved in a university's research incubator. Some consented students were participating in the research incubator performing additional projects for the same client. Those projects provided them with more opportunities to develop design skills. Consequently, we purposefully selected only three teams who were not part of that extracurricular activity, aiming that the teams' skills were mostly influenced by the structure of the new course project. Namely, Table II displays the distribution of the selected teams.

TABLE II
COMPOSITION OF THE EXPLORED TEAMS

Team	Course Section	Team Composition
Team A	Section 2	3 Male
Team B	Section 2	4 Male
Team C	Section 1	2 Male, 1 Female

E. Data Collection and Analysis

We collected students' artifacts associated with their design process including their 12 sprint reports, the slides of their presentations, feedback from the instructor, and worksheets associated with planning the goals for Project 3. Additionally, we videorecorded the intermediate teams' presentations to the client, the introduction to Project 3, and their final presentations. Finally, we interviewed the students, the instructor, and the client to better understand their experience and perceptions of the project. The original data was collected in Spanish, so we translated it to report the results of the current study.

Two researchers analyzed the collected data qualitatively [33] through several cycles of engagement, coding, and interpretation. First, two researchers reviewed all the data to develop an overall understanding of the project and wrote analytic memos capturing initial insights into when and how students demonstrated problem-framing skills. The analysis then focused on each team's 12 sprint reports, as well as recordings of the introduction to Project 3 and the client presentations. Guided by our preliminary analysis and theoretical framework, the data were coded using concept codes [34]: *"defining needs and requirements"* and *"staying tentative and iterating between problem and solution spaces"*. Then, the initial patterns were discussed with the rest of the research team, including the class instructor and expert researcher in design learning, to determine the patterns' relevance and meaning. Based on this discussion, the instructor's initial interaction with the client was identified as a pivotal moment that shaped later learning experiences. Finally, the team collaboratively refined the reporting of the main findings and interpretations.

IV. TRUSTWORTHINESS

We followed the guidance of Merriam and Tisdell [33] to promote the trustworthiness of this study in terms of validity and reliability. We employed data triangulation by collecting multiple data sources, including student artifacts and classroom video recordings, and investigator triangulation by involving at least two researchers in data collection and analysis. Two researchers also served as course instructors, enabling prolonged engagement with participants and facilitating close access to students' experiences during the engineering project. Finally, we provide rich contextual descriptions and include direct evidence from students (e.g., interview excerpts and artifact samples), allowing readers to assess the transferability of the findings to their own contexts.

V. Findings and discussion

The teams fostered their problem-framing skills when working on the client-based project. They were able to identify client needs and translate them into requirements and technical specifications. They practiced exploring the problem and solution space iteratively until developing a prototype that met the clients' expectations. Based on our data analysis, three themes emerged on how the client-based project supported students' development of problem framing skills, we include three themes in this section. First, the initial instructor and client negotiation to set the project for the students; second, the planning for Project 3 session as an opportunity to discuss the problem; and three, the engagement with multiple stakeholders to foster iteration of the solution.

A. Initial Instructor-Client Negotiation: Setting Conditions for Student Framing

Prior to the start of the academic semester, during the intersession period, representatives from the Colombian Port approached the Division of Engineering to present a set of seven operational problems for potential academic collaboration. These problems spanned different functional areas within the port and varied in technical scope and complexity. Following an initial analysis, the course instructor evaluated the proposed challenges considering three criteria: alignment with the learning outcomes of the Electronic Design course, the pedagogical feasibility of addressing the problems within a semester-long project-based learning framework, and the instructor's own technical expertise. As a result of this analysis, three of the seven challenges were selected to be addressed within the course. It is important to note that Electronic Design had been grounded in Project-Based Learning well before incorporating client-based dynamics. The instructor and the client agreed to engage directly with the students throughout the semester. This sustained involvement positioned the client not merely as a problem source, but as an active stakeholder in the learning process, reinforcing the authenticity of the design experience while preserving the instructional coherence of the course.

The initial negotiation with the Colombian Port Representatives was vital to ensure that students would have the required agency to foster their problem-framing skills. The Colombian port representatives communicated with the class instructor to seek support in improving their operations within the port using technology. They presented several needs, including (1) ensuring strict monitoring of container movements in accordance with the guidelines established by the port's planning office; (2) guaranteeing controlled access for truck drivers involved in any container movement operations; and (3) enabling real-time monitoring of truck trajectories within the container yard.

In addition to exploring the clients' interests, the instructor also had to consider the students' learning outcomes. The course aimed to support students' development of engineering design skills while simultaneously fostering learning related to IoT and the construction of telecommunications infrastructure. Furthermore, the instructor was interested in minimizing changes to the original course structure and keeping the project aligned with his area of expertise, namely telemetry systems development. Consequently, he proposed focusing the project on designing a telemetry system capable of tracking the movement of cargo-handling vehicles inside the port. Given that the course traditionally centers on telemetric system development, this design focus preserved the logistical feasibility of the course while addressing the client's operational needs.

This initial negotiation illustrates a broader pedagogical consideration for instructors seeking to implement classroom innovations that combine client-based projects, project-based learning, and agile methodologies. Such innovations require a deliberate negotiation and alignment among three key elements: (1) the needs and expectations of the client, (2) the intended learning outcomes of the course, and (3) the instructor's own level of expertise and professional experience. In this case, balancing these elements was essential to create a design space that was both educationally meaningful and operationally realistic, while remaining manageable within the constraints of a semester-long course.

As an expert designer, the instructor framed the problem by synthesizing the client's needs with these pedagogical and contextual constraints, proposing an initial solution hypothesis. He identified the primary stakeholders as the Colombian Port Representatives, the students, and the university, and drew upon his prior experience to define the design problem. This framing resulted in two mandatory requirements: (1) designing a system capable of tracking and recording the position of a vehicle inside the port during a specified time frame, and (2) designing a system to visualize the position and movement of the vehicle within the port over that same period.

However, this initial framing was largely performed by the instructor, which limited opportunities for students to engage in the types of framing practices demonstrated during the negotiation. To address this limitation, the research team and the instructor agreed to introduce a third, optional requirement that would be entirely framed by the student teams, provided that the two mandatory requirements were met. The Colombian Port Representatives were informed that, in addition to fulfilling the core requirements, students would also generate an added-value proposal tailored to the client's needs.

B. Opportunities to translate client needs into requirements

Expert designers frame problems by analyzing client needs and translating them into design requirements. While Projects 1 and 2 supported the development of students' technical and analytical skills for building functional prototypes, the instructor-defined goals limited opportunities for students to engage in problem framing. In contrast, Project 3 required students to identify relevant client needs, propose additional requirements, and operationalize them based on the feedback received from the Colombian Port Representatives during the intermediate presentation. Team A addressed port cybersecurity by proposing a fingerprint-based driver authentication device combined with the encryption of drivers' location data. Team B focused on operational inefficiencies caused by prolonged vehicle presence and suboptimal routing, proposing a control panel that receives vehicle location data and enables the Operations Manager to assign routes and regulate dwell time. Team C addressed the risk of cargo damage by proposing a vibration-sensing device to detect potential threats to delicate loads. Table III shows the goals for each sprint proposed by the teams to materialize their proposals.

TABLE III
GOALS PROPOSED BY THE TEAMS AS DELIVERABLES FOR PROJECT 3

Sprint	Team A goals	Team B goals	Team C goals
P3S1	Ensure information transmission between the ESP32 and the server through encryption and HTTPS.	Trace the historical route of the vehicle to address the question: "When did the vehicle pass through a specific location?" Integration of street maps with Leaflet in the WebServer and map visualization within the mobile app.	Adapt the web/app infrastructure for multi-user support (vehicles), maintaining geolocation visualization and historical vehicle queries.
P3S2	Optimize the storage and analysis of coordinates using the PostGIS extension.	Implement multiple devices and develop the user authentication platform. Visual signaling of congested streets on the mobile app map and the website.	Configure the Database (RDS PostgreSQL) for the collection of information sent by the vehicle and the theoretical PCB design for the vibration sensor.
P3S3	Build a visual interface that allows for the real-time monitoring of vehicles and zones.	Trace the route according to the destination assigned to each device by the control tower from the web server. Display the shortest path within the mobile app.	Implement of logic for metric calculation in the web service and the creation and validation of the initial prototype (perforated board).
P3S4	Incorporate geofencing functions and spatial analysis using PostGIS.	Develop alert system in case the driver deviates from the route.	PCB implement and service calibration (Load monitoring) with tests to ratify integrated operation. Implement heat map.

Proposing goals and requirements aligned with client needs was not straightforward for all teams. Team C anticipated the Colombian Port's interest in scalability and efficiency and, by the end of Project 2, incorporated a load balancer into the system architecture to address these needs. Moreover, for Project 3, they planned to sense cargo vehicles' vibrations to identify potential risks to the load. In contrast, during the reflection session, Team A proposed a hardware-based solution that did not align with the client's primary objective; namely, the Team was planning to develop a device to monitor vehicles outside the Port, as the following excerpt illustrates:

> **Student:** [Describes a device to track vehicles when leaving the port]
> **Instructor:** But the tracking system is only for the <u>interior</u> of the Port, right?
> **Student:** No, not only for the interior... Does the system require focusing only inside the port?
> **Instructor:** As far as I understand... the monitoring is *inside* the port. When they [the vehicles] leave, they [the client] know they left; they are no longer interested in where they went.
> **Student:** I understood the opposite...
> **Instructor:** Before thinking about the *solution*, think about the *need*. And that [monitoring outside] is not a priority need. The priority for them is what happens inside.

Team A's proposed solution—using hardware to monitor vehicles outside the Port—was misaligned with a core problem entity, as the client's main interest concerned monitoring operations within the Port. The interaction with the instructor during the reflection session prompted the team to evaluate their solution entities and discard the external monitoring approach, leading them to redefine their proposal as a hardware-based system to track the cargo vehicles' location inside the Port. Engaging with a real client within a specific context helped the team recognize that, although their initial idea was technically appropriate for an electronic engineering project, it did not meet the design project's requirements and was therefore inadequate. Students learned the importance of aligning problem and solution entities when working on design problems, in contrast to traditional algorithmic problems.

C. Multiple stakeholders provide input and the need for iteration

During the intermediate presentation to the client, all teams presented a preliminary prototype to the Colombian Port Representatives. The three teams had developed a system that stored and displayed the position and trajectory of a cellphone on a website using their personal devices as a simulation of cargo-handling vehicles' movement inside the Port. Although their systems fulfilled the general requirements presented at the beginning of the semester, they partially met the clients' needs. Namely, Team B and Team C presented previous simulations of their phone moving, so the client could validate the requirement. However, the Port Representatives were not satisfied with the system because it depicted the vehicle movement in the map as straight lines, considering only the start and end geocoordinates (See Fig. 1), which failed to represent actual movement along the Port's road network.

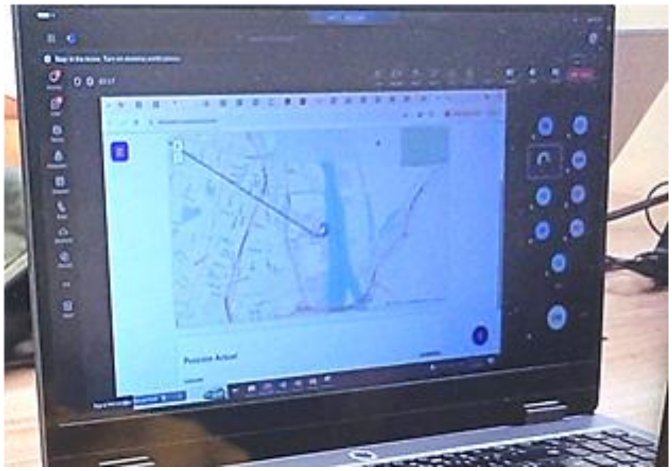

Fig. 1 Team B preliminary prototype displayed during the intermediation presentation to the client.

One of the stakeholders emphasized that accurately displaying vehicle positions along specific roads was essential and explained that the system should rely on geofences rather than raw geocoordinates. Furthermore, the operation manager mentioned his interest in measuring dwell time within those geofence zones and detecting transitions between areas to improve productivity. At the end of the intermediate presentation, the overarching initial requirement evolved from simply displaying location data to supporting operational decision-making within the Port through meaningful spatial boundaries (geofences) and continuous visibility.

Taken together, the findings suggest that real-client projects may support students' problem-framing skills when they are deliberately structured to balance authenticity with pedagogical and logistical feasibility while also preserving students' framing agency. In this study, the initial negotiation between the instructor and the Colombian Port representatives established an authentic yet manageable design space, and the optional third requirement in Project 3 created room for students to make consequential decisions about which client needs to prioritize and how to address them. Although authentic and client-based projects are often presented as promising settings for design learning, they do not necessarily support problem framing when the work is too tightly predefined [6], [22], [23]. Here, Project 3 supported students' agency by positioning them to identify needs, constraints, and requirements; revise initial ideas when they did not align with stakeholder priorities, as in Team A's shift away from external monitoring; and use prior technical knowledge and judgment to propose added-value functionalities. In this sense, the project did more than provide an authentic context; it enabled students to exercise agency in shaping design directions, consistent with prior work that characterizes problem framing as a central engineering design practice [15], [20], [22], [23].

VI. Limitations and Future Work

Our study has limitations that should be considered when interpreting the findings. We are reporting on the first iteration of a design-based research project with a limited number of participants. Thus, we approached the study with a qualitative constructivist stance looking for deeper understanding rather than generalizations. Our findings aim to support instructors with similar contexts who want to implement client-based projects. For future work, we are planning to carry out new iterations of the course with different clients and more participants to provide a more robust framework for the design of client-based projects that help students to develop problem-framing skills.

We recognize the importance of including the perspectives of a variety of students including different gender identities. Unfortunately, the studied classroom included only three women among 27 students. Of these, only one was included in the present analysis, as the others participated in extracurricular activities that could confound the findings. Future studies should aim for a more balanced sample and could intentionally examine gender-related differences.

Finally, it is important to mention that the course instructor had several years of experience teaching the class and working with real clients. Further research could explore how instructors with different levels of expertise facilitate client-based projects to support problem-framing.

VII. Conclusions

Overall, our findings suggest that the proposed client-based project may support students' problem-framing skills. Across the explored teams, students identified client needs and translated them into requirements and technical specifications, iteratively exploring both the problem and solution spaces until producing prototypes that aligned with client expectations. Our analysis revealed three interrelated mechanisms through which the project fostered problem framing: (1) early negotiation between the instructor and the client to establish an authentic yet pedagogically viable project, (2) intentional structuring of Project 3 sessions as spaces for collective problem exploration, and (3) sustained engagement with multiple stakeholders that prompted iterative refinement of both the problem definition and the proposed solution.

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