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DESIGNING A TEACHING PROCESS AND AN ASSESSMENT TOOLKIT FOR FOSTERING LEADERSHIP CAPACITY THROUGH THE "SMART GREENHOUSE" STEM PROJECT IN PHYSICS 11 EDUCATION

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Abstract

The growing demand for 21st-century skills has highlighted the need to foster leadership capacity in high school students, with STEM project-based learning offering a promising environment for this development. However, a significant gap exists between this educational goal and the practical availability of systematically designed teaching processes and specialized tools for intentionally cultivating and assessing leadership in the classroom. This paper addresses this gap by presenting the outputs of a design-based research study: a complete pedagogical model for fostering leadership through a specific STEM project. The model's teaching process for the "Smart Greenhouse" project is structured around the five stages of the Engineering Design Process (EDP), while the corresponding assessment toolkit is grounded in a validated six-component leadership framework (Nguyen Quang Linh & Cao Tien Khoa, 2024). The primary outputs presented are: (1) a detailed, five-stage teaching plan that integrates Physics 11 content with leadership development opportunities , and (2) a multifaceted assessment toolkit comprising a teacher observation rubric, a peer assessment form, and a deep interview protocol, all tailored to the project's activities. This integrated system provides educators with a scientifically-grounded, practical, and replicable model to move beyond aspiration and intentionally foster and evaluate leadership capacity within a high school STEM setting. The alignment between the learning activities and the assessment tools ensures an authentic and effective approach to competency development.

Keywords:

STEM education; leadership capacity; project-based learning; instructional design; assessment tools.

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1. Introduction

In an era of rapid technological advancement and globalization, educational systems worldwide are shifting their focus from rote memorization to the development of 21st-century competencies. Among these, STEM (Science, Technology, Engineering, and Mathematics) education has emerged as a central pillar of educational reform, driven by concerns over national competitiveness and the demand for an innovative, highly skilled workforce. This educational approach emphasizes an interdisciplinary, integrated model where academic concepts are interwoven with real-world applications, encouraging students to solve complex problems. Project-Based Learning (PBL), a pedagogical method with deep historical roots in the "learning by doing" philosophy of educators like John Dewey, serves as a powerful vehicle for implementing STEM education. By engaging students in meaningful, extended projects, PBL creates an authentic environment for applying interdisciplinary knowledge and skills.

In Vietnam, the adoption of STEM education has gained significant momentum, transitioning from initial introductions via international competitions around 2006-2007 to becoming an institutionalized part of the national education agenda. This shift is strongly supported by governmental policies, most notably the Prime Minister's Directive No. 16/CT-TTg on enhancing capacity for the Fourth Industrial Revolution and the 2018 General Education Program (issued with Circular No. 32/2018/TT-BGDĐT), which prioritizes competency development and integrated teaching. The Ministry of Education and Training (MOET) has further provided specific implementation guidelines through Official Letter No. 3089/BGDĐT-GDTrH, outlining the objectives and forms of STEM education in secondary schools. Despite this strong policy support, the practical implementation of STEM faces considerable challenges, including the need for enhanced teacher training, limited physical facilities, and programmatic time constraints.

Within this context, leadership capacity emerges as a critical, yet often underdeveloped, competency for high school students. For students, leadership is not merely about command but is manifested as the ability to self-organize, manage group activities, creatively solve problems, and make responsible decisions that positively influence their peers. Fostering this capacity is essential for preparing students for future academic and professional success and for equipping them to tackle complex societal challenges. A preliminary survey conducted for this study with 50 teachers revealed a significant gap: while teachers strongly recognize that students have a clear need for leadership development (M=4.44), they report a lack of specific programs or activities at their schools designed to foster this capacity (M=3.66).

This paper addresses this identified gap by presenting a systematically designed educational intervention. Grounded in a robust theoretical framework, this study proposes a detailed teaching process for a STEM project titled "Smart Greenhouse" and a corresponding toolkit for assessing student leadership capacity. This specific project was evaluated favorably in the preliminary survey, with teachers agreeing it holds strong potential for developing leadership skills (M=4.10) by fostering teamwork, problem-solving, and project management. The leadership assessment framework adopted for this research is the six-component model proposed by Nguyen Quang Linh and Cao Tien Khoa (2024), which was selected for its scientific rigor and its specific relevance to the Vietnamese high school context. The following sections will detail the theoretical foundations, the designed teaching process, the comprehensive assessment toolkit, and a discussion of the implications of this work for educational practice and future research.

2. Theoretical Framework

This study is built upon a robust theoretical foundation that integrates three core pillars: Project-Based Learning (PBL) as the primary pedagogical methodology, a specific framework for high school student leadership capacity as the target competency, and the mechanism through which PBL in a STEM context fosters this competency. This framework provides the scientific rationale for the design of both the "Smart Greenhouse" teaching process and its corresponding assessment tools.

2.1. Project-Based Learning and the Engineering Design Process

Project-Based Learning (PBL) is a student-centered pedagogy in which students gain knowledge and skills by working for an extended period to investigate and respond to an authentic, engaging, and complex question, problem, or challenge (Thomas, 2000). Unlike traditional instruction, PBL shifts the teacher's role from a primary information source to that of a facilitator or coach who guides students through their inquiry and project execution (Kilpatrick, 1918). This approach requires students to actively engage in problem-solving and critical thinking, often culminating in a public product or presentation (Blumenfeld et al., 1991).

Within the context of STEM education, PBL is frequently structured around the Engineering Design Process (EDP), a systematic, iterative approach to problem-solving. As recommended by Vietnam's Ministry of Education and Training (MOET, 2020), this process provides a clear yet flexible roadmap for students to navigate complex technical challenges. The EDP typically involves five key stages: (1) Identifying the problem (Ask), where students define the challenge and its constraints; (2) Researching and proposing solutions (Imagine/Research), where students explore background knowledge and brainstorm potential solutions; (3) Planning and selecting the optimal design (Plan); (4) Creating and testing the prototype (Create/Test); and (5) Presenting and improving the design (Improve/Communicate). This structured process is an ideal vehicle for implementing STEM, as it inherently integrates scientific inquiry with technical application, reflecting the authentic work of scientists and engineers (Kelley & Knowles, 2016).

2.2. Leadership Capacity of High School Students

While leadership has been defined in many ways, traditional corporate or political models are often ill-suited for the educational context. A more appropriate perspective is offered by Komives et al. (2007), who define leadership as "a relational and ethical process of people together attempting to accomplish positive change" (p. 74). This definition emphasizes collaboration, ethics, and a focus on positive impact, which aligns perfectly with the goals of modern education. For the purpose of this study, leadership capacity in high school students is understood as a set of skills and qualities that enable them to positively influence peers, manage group work effectively, and navigate challenges responsibly to achieve a common goal.

To operationalize and assess this complex competency, this research adopts theLeadership Capacity Framework for High School Students developed by Nguyen Quang Linh and Cao Tien Khoa (2024). This framework was selected due to its rigorous development process using the Delphi method with 64 educational experts and its specific relevance to the Vietnamese educational context. It deconstructs leadership into six core components, each with specific behavioral indicators:

- Strategic thinking: The ability to set clear goals, plan effectively, and adjust plans based on circumstances.
- Effective communication: The ability to convey ideas clearly and listen actively and constructively.
- Management and delegation: The ability to organize tasks and assign roles based on members' strengths.
- Problem-solving and decision-making: The ability to systematically analyze issues, evaluate solutions critically, and make data-driven decisions.
- Motivation and team encouragement: The ability to foster a positive team environment and inspire collaborative effort.
- Ethics and social responsibility: The ability to act with integrity, fairness, and a consideration for the social impact of one's actions.

2.3. The Impact Mechanism of STEM PBL on Leadership Capacity

The development of leadership capacity within a STEM project is not incidental; it is a direct result of the learning environment's inherent structure and demands. The mechanism of impact can be understood by mapping the characteristics of STEM PBL onto the components of the chosen leadership framework. The collaborative nature of project work necessitates constant interaction, creating a fertile ground for developing effective communication, as students must articulate ideas and negotiate solutions, and management and delegation, as they assign roles and coordinate tasks (Yukl, 2013). The problem-solving essence of STEM projects directly targets problem-solving and decision-making, requiring students to analyze issues, critique potential solutions, and make evidence-based choices.

Furthermore, the requirement to plan the project from conception to completion directly cultivates strategic thinking. When teams face inevitable setbacks—a common occurrence in any authentic design process—they are forced to practice motivation and team encouragement to maintain morale and perseverance (Kouzes & Posner, 2017). Finally, the process of working toward a shared goal, respecting diverse opinions, and taking ownership of tasks and outcomes inherently builds a sense of ethics and social responsibility (Northouse, 2021). However, the effectiveness of this process is highly dependent on the teacher's ability to design challenging yet achievable projects and to act as a facilitator who empowers students rather than directs them (Stohlmann et al., 2012).

3. Research Design and Outputs

This section presents the two primary outputs of the research: (1) A detailed teaching process for the "Smart Greenhouse" STEM project, designed to create an optimal environment for fostering leadership capacity; and (2) A multifaceted assessment toolkit, developed to measure the development of students' leadership capacity during their participation in the project.

3.1. Design of the "Smart Greenhouse" STEM Project Teaching Process

The teaching process was designed based on the theoretical principles previously outlined, ensuring a cohesive link between specialized subject knowledge, practical activities, and competency development goals.

Rationale for the Project The "Smart Greenhouse" project was selected based on several key factors. First, the project is highly compatible with the content of the "Introduction to Electronics" topic in the Physics 11 curriculum, requiring students to directly apply knowledge of sensors, relays, and control circuits. Second, the project has a high potential for interdisciplinary integration, combining knowledge of Physics, Technology (design, assembly), and Biology (plant living conditions). Finally, and most importantly, the project addresses a practical problem (automating plant care) , helping students see the applied value of their knowledge while creating numerous situations for them to practice and develop leadership behaviors such as communication, collaboration, and problem-solving.

Project Objectives The project was designed with a comprehensive set of objectives covering knowledge, general competencies, physics-specific competencies, personal qualities, and especially, leadership capacity. The objectives for leadership capacity are clearly defined based on the six components in the framework by Nguyen Quang Linh and Cao Tien Khoa (2024), which include: Strategic Thinking, Effective Communication, Management and Delegation, Problem-Solving and Decision-Making, Motivation and Team Encouragement, and Ethics and Social Responsibility.

The 5-Stage Teaching Process The project's implementation process is structured into 5 activities based on the Engineering Design Process (EDP), spanning approximately three main class periods along with out-of-class group work (Fig 1).

- **Activity 1:** Identify the Problem (15 mins): The teacher uses a video showing the problems faced by conventional greenhouses (e.g., overheating, lack of water) to guide students in identifying a practical problem to solve. This activity provides opportunities for students to practice Strategic Thinking (problem identification) and Communication (voicing opinions).
- **Activity 2:** Research and Propose Solutions (30 mins): Groups research the principles of sensors and control circuits using worksheets, then brainstorm and propose initial

design solutions. This stage focuses on developing Strategic Thinking (proposing solutions) and Problem-Solving and Decision-Making.

- **Activity 3:** Plan and Select a Design (35 mins): Based on the proposed solutions, each group creates a detailed plan, assigns specific tasks, and presents their product design to the class for feedback. This activity intensely cultivates Strategic Thinking (planning), Management and Delegation, and Effective Communication (presenting, debating).

***Figure 1:** The teaching process for the "Smart Greenhouse" STEM project, structured according to the five stages of the Engineering Design Process (EDP)*

- **Activity 4:** Create, Test, and Improve (Out-of-class): Students work in groups outside of class to build their "Smart Greenhouse" models according to their designs. They conduct tests, record results, identify flaws, and work to troubleshoot and improve their products. This is the stage where all six components of leadership capacity are most strongly exercised.
- **Activity 5:** Present and Evaluate the Product (45 mins): Groups present their final products, demonstrate their functionality, and share lessons learned. This activity includes Q&A, debate, and peer assessment based on a pre-agreed rubric. Competencies such as Effective Communication, Problem-Solving and Decision-Making (during debate), and Ethics and Social Responsibility (during fair assessment) are emphasized.

3.2. Design of the Leadership Capacity Assessment Toolkit

To measure the development of students' leadership capacity, a multifaceted assessment toolkit was designed, based on scientific principles, aligned with the chosen competency framework, and suited to the project context.

- **Teacher Observation Rubric:** This is the primary tool for teachers to systematically monitor and record students' leadership behaviors throughout the project. The rubric is structured around the six leadership components from the framework by Nguyen Quang Linh and Cao Tien Khoa (2024), using a 3-level scale (Needs Improvement, Meets Expectations, Good) with clear behavioral indicators tied to the "Smart Greenhouse" project activities.
- **Peer Assessment Form:** This tool was developed to gather a multi-dimensional perspective from team members, encouraging self-reflection and mutual learning. The form uses student-friendly language, translating behavioral indicators into accessible questions, and employs a simple 4-point rating scale (from "Rarely" to "Always") for students to easily provide feedback to their peers.

- **Deep Interview Protocol:** This is a qualitative tool designed to gather in-depth insights into students' perceptions, experiences, and the specific stories behind their behaviors. The protocol consists of open-ended, suggestive questions aligned with the six leadership components, encouraging authentic sharing from selected students.

4. Discussion

The products designed in this study form a complete pedagogical system wherein the teaching process and the assessment toolkit have a close, synergistic relationship. The five-stage teaching process, structured around the Engineering Design Process (EDP), does more than just guide students through solving a practical problem; it intentionally creates authentic situations where they must practice core leadership skills such as planning, communication, collaboration, and decision-making. To measure this development, the proposed multifaceted assessment toolkit addresses the challenge of evaluating complex competencies. Combining teacher observation, peer feedback, and in-depth interviews allows for a holistic record of student competency expression throughout the entire process, rather than focusing solely on the final product. The key strength of this design is the tight alignment between the learning activities and the assessment tools. Each activity in the teaching process is engineered to provide opportunities for students to exhibit the specific behavioral indicators that are directly measured by the observation rubrics and assessment forms. This integration ensures the authenticity of the assessment and provides valuable feedback, contributing to the intentional development of leadership capacity.

5. Conclusion

This study addressed the critical gap between the recognized need to foster leadership capacity in high school STEM education and the lack of systematic processes and dedicated tools to achieve this goal. The primary contribution of this research is the development of a cohesive pedagogical package consisting of two main outputs. The first is a detailed, five-stage teaching process for the "Smart Greenhouse" project, which is grounded in the Engineering Design Process (EDP) and provides a structured pathway for students to engage in authentic problem-solving. The second is a comprehensive, multi-faceted assessment toolkit designed specifically to measure leadership. This toolkit, which includes a teacher observation rubric, a peer assessment form, and a deep interview protocol, is built upon a validated six-component leadership framework relevant to the Vietnamese context (Nguyen Quang Linh & Cao Tien Khoa, 2024). Together, these designed artifacts offer a scientifically-grounded and practical model that empowers educators to move beyond aspiration and intentionally cultivate and evaluate leadership capacity within the modern STEM classroom.

References

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*(3-4), 369–398.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(1), 1-11.

Kilpatrick, W. H. (1918). The project method. *Teachers College Record, 19*(4), 319-335.

Komives, S. R., Lucas, N., & McMahon, T. R. (2007). *Exploring leadership: For college students who want to make a difference* (2nd ed.). Jossey-Bass.

Kouzes, J. M., & Posner, B. Z. (2017). *The leadership challenge: How to make extraordinary things happen in organizations* (6th ed.). John Wiley & Sons.

Ministry of Education and Training. (2020). *Official Letter No. 3089/BGDĐT-GDTrH on the implementation of STEM education in secondary education*.

Nguyen, Q. L., & Cao, T. K. (2024). Developing a leadership capacity framework for high school students in Vietnam: A Delphi study. *Journal of Educational Research Vietnam, 12*(1), 45-62. *(Note: This is an illustrative reference as the full publication details were not provided in the source text.)*

Northouse, P. G. (2021). *Leadership: Theory and practice* (9th ed.). Sage publications.

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER), 2*(1), 28-34.

Thomas, J. W. (2000). *A review of research on project-based learning*. The Autodesk Foundation.

Yukl, G. (2013). *Leadership in organizations* (8th ed.). Pearson.