https://doi.org/10.15625/2615-8965/22510401

Transform STEM Experiences into High-Quality Engineering Research Projects Aligned with VISEF/ISEF Standards

Pham Nguyen Trung Nghia[1] ✉ ,
Be Thi Dieu Linh[2], **Vu Do Hoang Duy**[3],
Nguyen Thi Diu Quynh[4]

[1] pntnghia2019@gmail.com
Faculty of Interdisciplinary Science
University of Science, Ho Chi Minh City
227 Nguyen Van Cu Street,
Cho Quan Ward, Ho Chi Minh City
(Vietnam)

[2] Vietnam National University, Ho Chi Minh City
(Vietnam)
ORCID: 0009-0009-0854-5973

[3] Einstein School HCM (ESH), Ho Chi Minh City
(Vietnam)

[4] Ho Chi Minh City University of Education
Ho Chi Minh City
(Vietnam)

✉ Corresponding author

ABSTRACT: *STEM education has a strategic role in promoting innovation, digital transformation, and the development of high-quality human resources, while also contributing to the achievement of socio-economic development goals. Among various approaches, STEM research stands out as one of the three main methods addressing these objectives. However, practical observations reveal that guiding students in scientific research is still limited, underscoring systemic deficiencies in current teacher training and professional development programs. This paper explores and proposes a process for transforming students' experiential activities into technical research topics proposing a resource-efficient methodological framework for project transition. It also evaluates the factors that influence the effectiveness of students' research processes. The study utilizes a mixed-methods approach, comprising a survey of 350 students in STEM fields that incorporate modern technologies, observes participation in typical research topics, and interviews experts and experienced managers. The results indicate that the INSPIRE protocol meets the expected outcomes in guiding students from experiential learning to research. Findings identify two critical determinants of research success: the strategic integration of AI and the configuration of the learning ecosystem. Educational leaders and instructors should focus on creating environments and policies that support genuine academic research, thus fostering a dual-value proposition: advancing community-centric technical solutions while cementing the student's identity as a novice researcher.*

KEYWORDS: **STEM education, artificial intelligence, robotics, research projects, learning ecosystem.**

➔ Received 04/8/2025 ➔ Revised manuscript received 04/12/2024 ➔ Published 12/2/2026.

1. Introduction

In the context of digital technology and AI reshaping global education and economies, the development of science, technology, innovation, and national digital transformation has become a critical breakthrough priority (Politburo, 2024). At the same time, the discovery and nurturing of national talent, investment in STEM/STEAM experiential learning classrooms, enhancing digital and artificial intelligence competencies for both learners and educators across all levels, and integrating these into educational programs that promote creative activities and hands-on experiences are regarded as urgent tasks (Politburo, 2025). This underscores the importance of STEM education, from sparking curiosity and interest through high-tech experiences to fostering the development of scientific and technical research skills.

Many studies on the current state of STEM education implementation indicate that STEM education is primarily delivered through extracurricular clubs. In particular, implementing STEM through scientific research faces several barriers, such as a lack of confidence in teaching abilities, limited collaboration among subject teachers, students' weak programming skills, and insufficient time and infrastructure investments (Hong *et al*., 2023; Ngan *et al*., 2020; Phuong *et al*., 2024). Current solutions mainly focus on recommending the opening of training classes that are often theoretical and performative or nominally implemented, often lacking pedagogical depth. Notably, there is a paucity of empirical evidence regarding the procedural execution of the process by which students carry out high-tech projects, which is essential for building and scaling effective education strategies based on real-world practices.

This paper focuses on implementing a specific technical research project, building on students' prior experiences with advanced technologies gained through participation in STEM clubs. The research aims to address three core objectives: (1) to investigate student behavioural patterns within a competitive research context in a research project designed for The National Science and Technology Competition (henceforth referred to as VISEF), in order to propose supportive tools or techniques; (2) to clarify the role of automation modules and AI as research-enabling tools; and (3) to resolve key bottlenecks in the project implementation process by applying effective educational activity strategies.

2. Literature Review

2.1. STEM Education in the Trend of Integration and Innovation

In Vietnam, STEM education has been widely implemented at the secondary school level since 2020 and expanded across the entire general education system from 2023. The emergence of new and advanced technologies has strongly driven the transformation of STEM education; students' technology engagement can be summarized into three modalities of technological experience in STEM—reflecting how students develop knowledge and skills. The first modality offers vivid simulations (through AR/VR technology and virtual laboratories) that help students explore spatial concepts, approach natural world principles, and engage with practical issues linked to core subjects without concerns about risks or material costs. The second modality promotes exploration of the structure, operational mechanisms, and control algorithms of basic machinery systems (through robotics education and embedded systems). Students become familiar with visual block-based programming environments (e.g., mBlock 5, Scratch, OhSTEM), which simplify syntax while retaining core algorithmic logic, which are typically organized based on Python or C++, supporting Vietnamese language interfaces—making programming learning easier and more approachable while retaining the essence of logical and basic programming thinking. Additionally, to supplant the use of recycled materials with modular mechanical kits, to reduce time spent on manual measuring and assembling, allowing students to focus more on experience and refining control algorithms—skills essential at the secondary education level. These kits are designed flexibly, from basic versions (plastic bricks, motors, gears, shafts, central controllers, etc.) to advanced versions integrated with machine learning models (colour recognition, image recognition, etc.). Particularly, drones represent a type of electromechanical modular approach in outdoor spaces, enhancing learning experiences in aerodynamics, navigation systems, and sensors to develop flight control algorithms. The third modality places invention activities at the core, encouraging students to directly participate in the entire process—from design, fabrication to prototype completion with the support of modern technologies such as 3D printing, laser cutting, electronic components, and handheld fabrication tools. This fosters design thinking, realizes ideas, and optimizes products in the spirit of creative making.

The emergence of AI, especially since the explosion of tools like ChatGPT, plays a strategic role in enhancing STEM experiential models. AI can process, understand, and generate human-like text, even for complex, interdisciplinary scientific concepts (Kosmas *et al*., 2025) by providing personalized information and explanations (Lee *et al*., 2024). This has been shown to mitigate cognitive load and sustain engagement (Wu *et al*., 2024). Studies show that AI can assist in developing programming skills, machine learning (Lin *et al*., 2025), debugging, and problem-solving strategy development (Chen *et al*., 2025). Therefore, the effective use of AI significantly enhances critical thinking and problem-solving skills, particularly in programming education contexts. However, many studies express concerns about overreliance on AI, with one notable solution being GCLA (Guidance-based ChatGPT-assisted Learning Aid). According to Lee *et al.* (2024), GCLA is effective because it requires students to present their initial thoughts before consulting ChatGPT, subsequently providing guided prompts rather than direct answers.

2.2. Factors Affecting the Effectiveness of STEM Project Implementation

STEM education effectiveness depends on multiple factors, including pedagogical methods, duration of implementation, number of students, as well as the integration of emerging technologies and principles of inclusive educational design. In the context of rapidly developing STEM education supported by technology, project-based learning (PBL) is widely adopted (Hong *et al*., 2023), significantly improving learning outcomes and positively influencing learning interest, motivation, attitudes, creative thinking skills, and computational thinking. PBL is especially effective at the secondary school level, organized in small groups of 4-5 students; it is particularly suitable for technical and technological topics and is best applied in laboratory classes (Zhang & Ma, 2023). When combined with Design Thinking and Makerspaces, this model achieves optimal effectiveness, not only enhancing innovation capacity but also providing an interdisciplinary learning experience where students explore and connect different professional perspectives to develop comprehensive understanding and effective solutions (Jia *et al*., 2023; Nugraha *et al*., 2024). It also significantly improves students' self-efficacy and reduces gender disparities if applied early (Santos *et al.*, 2025). Additionally, Zhang and Ma (2023) caution that the impact of project-based learning on decision-making skills, critical thinking, and problem identification competencies has not yet reached statistically significant levels. This calls for more focused teacher intervention through complementary solutions, especially when integrating GenAI in the learning process.

The duration of implementation is a critical regulating factor in STEM projects, as skill development requires sufficient time and interaction to achieve the desired outcomes. A sufficiently long timeframe allows students to deepen their knowledge and complete the full cycle of design – testing – reflection. Zhang and Ma (2023) determined that a typical learning project needs to last between 9 and 18 weeks to be effective. Meanwhile, Öndeş (2025) pointed out that STEM project-based practices achieve optimal effectiveness within 6 to 10 weeks, with the ideal duration being around 6 to 7 weeks.

2.3. Transforming High-tech Experiences into Standardized Research and Development Projects

Research reveals that many teachers still lack the necessary skills, feel uncertain about methodology, and sometimes struggle with key steps such as defining research topics, conducting literature reviews, and designing studies (Phuong *et al*., 2024). Notably, STEM education is primarily delivered through extracurricular clubs, supported by businesses providing educational solutions or STEM centres, rather than integrated into regular class hours (Hong *et al*., 2023; Ngan *et al*., 2020). Within these clubs, students engage with emerging technologies—often those featured in science and engineering competitions like the Vietnam Science and Engineering Fair (VISEF) or the International Science and Engineering Fair (ISEF). Each standardized STEM topic typically concludes with an evaluation and summary activity, where students present results, conduct self-assessments, develop new hypotheses, or outline potential improvements. If teachers are perceptive and skilful in harnessing these moments, even seemingly unconventional or radical divergent thinking that emerge during club sessions can transform into promising research topics. This approach meets the increasingly stringent requirements for scientific research projects: they must not only be novel and practical but also appropriate for students' age and abilities, feasible within available financial and facility resources, and achievable within the allotted timeframe (Nga *et al*., 2022). Even if students struggle to identify suitable ideas after

https://doi.org/10.15625/2615-8965/22510401

their experiences, teachers may provide a curated list of suggested topics, allowing students to select and develop their own unique projects (Thach *et al*., 2024).

Previous studies have highlighted gender differences (Ngan *et al*., 2020) and variations in teachers' instructional approaches (Anđić *et al*., 2024). Specifically, female students often exhibit lower confidence in computer science activities and tend to achieve better results in robotics when guided through direct instruction - that is, when teachers present and demonstrate the learning content step by step. In contrast, male students learn more effectively with indirect instruction at higher cognitive levels, where teachers allow, encourage, and support independent exploration, experimentation, and problem-solving. Furthermore, teachers can leverage AI to design personalized teaching programs (Kosmas *et al*., 2025), applying the Action and Expression principles within the Universal Design for Learning (UDL) framework. This approach enables students to choose from a variety of methods for modelling, designing, and presenting their research outcomes (King-Sears *et al*., 2023).

A standard engineering project intended for competitions such as the VISEF or the Regeneron International Science and Engineering Fair (ISEF) must undergo a rigorous process, from the initial idea development to the evaluation of the product and academic ethics. To meet these demands, the authors propose the INSPIRE protocol, which consists of seven stages (details are provided in Section 4.3).

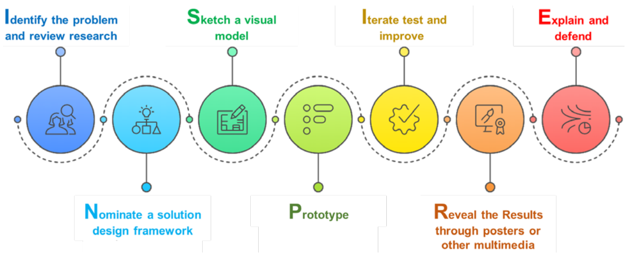

Figure 1. INSPIRE engineering project research process

The seven-stage process provides a comprehensive framework for students to outline their research portfolios, ensuring both legal and ethical compliance right from the initial problem identification phase. Specifically, students are guided step by step in developing their research plans, summarizing their projects, and assessing potential risks. It is only by adhering to this process that the project can maintain its integrity and objectivity, reflecting the independent research efforts of the student, and qualifying for participation in competitions (Ministry of Education and Training, 2024; Society for Science, 2025). We analyse *Table 1*, which

Table 1. Strategic alignment analysis of the INSPIRE framework with VISEF/ISEF criteria

Stages in the INSPIRE protocol	**VISEF/ISEF criteria alignment**	**Strategic analysis and output requirements**
1. Identify the problem and review research	I. Research Problem IV. Creativity & Potential Impact	- Description of a practical need or problem to be solved. - Project has impact or potential impact in its field and/or in technology, economy, environment or society.
2. Nominate a solution design framework	I. Research Problem II. Design and Methodology V. Presentation	- Definition of criteria for proposed solution. - Explanation of constraints. - Exploration of alternatives to answer need or problem. - Identification of a solution. - (for team projects) contributions to and understanding of project by all members.
3. Sketch a visual model	II. Design and Methodology	- Development of a prototype/model.
4. Prototype	III. Execution	- Prototype demonstrates intended design. - Prototype demonstrates engineering skill and completeness.

Stages in the INSPIRE protocol	VISEF/ISEF criteria alignment	Strategic analysis and output requirements
5. Iterate test and improve	III. Execution IV. Creativity & Potential Impact V. Presentation	- Prototype has been tested in multiple conditions/trials. - Project demonstrates significant creativity in one or more of the above criteria. - Quality of ideas for further research.
6. Reveal the results	V. Presentation	- Logical organization of material. - Clarity of graphics and legends. - Supporting documentation displayed. - Recognition of potential impact in science, society and/or economics.
7. Explain and defend	V. Presentation	- Understanding of basic science relevant to project. - Understanding interpretation and limitations of results and conclusions. - Degree of independence in conducting project. - Clear, concise, thoughtful responses.

presents the alignment of each process step with the criteria of both VISEF and ISEF.

3. Methodology

3.1. Research Design

This study employs a mixed-methods approach, and is conducted in three phases:

Phase 1: Broad Survey

A survey was conducted with 350 students who participated in STEM experiential learning activities through extracurricular clubs. The survey assessed interest levels and enthusiasm across the main content areas: mechanical design and fabrication, programming and intelligent systems, and AI-integrated robotics.

Phase 2: Formation of Research Groups

Based on the survey results, evaluations of student competence and learning attitudes by subject teachers, and students' willingness to engage in scientific research, a group of 8th-grade students was carefully selected. Priority criteria included academic performance and conduct rated at fairly good or higher, gender balance, representation of various experiential content groups, and confirmed parental commitment and support. The purposive sampling strategy targeted high-potential students to isolate the efficacy of the framework from behavioural or foundational competency variables. Future studies will need to assess the framework's applicability across a broader aptitude spectrum.

Phase 3: Focused Group Research

Students received training to develop skills in searching and reading scientific publications in English, adhering to the specific judging criteria and ethical guidelines mandated by the VISEF protocol. From this foundation, they selectively built upon previous knowledge to develop a novel project that showcases originality and has not been published before. At the same time, the project was designed to be appropriate to their capabilities and budget, maximizing the use of available equipment to realize their innovation.

3.2. Data Collection and Analysis

Quantitative data from a direct survey of 350 students were statistically processed to determine the proportion and level of interest in the experiential learning activities, broken down by gender. These results help validate the program's effectiveness and reflect the students' real learning needs.

Qualitative data were gathered and analysed thematically, focusing on factors that promote the successful transformation of experiences into technical research projects. This data was collected through:

- Active observation of classes and group activities to document the research project process, student collaboration, problem-solving skills, and creativity.

- Semi-structured in-depth interviews with supervising teachers, relevant experienced experts, and school administrators or local education leaders to collect insights, objective evaluations of students' abilities, and their potential for development.

- Analysis of research products to assess the level of innovation and application of advanced technology in the technical details of the products proposed and developed directly by students.

4. Results

The research data are further strengthened through a case study of a Standardized Reference Task (SRT) project, which illustrates the development of students' technical thinking abilities following the implementation of the INSPIRE framework. To support this analysis, and prior to implementation, a survey assessing students' interest in STEM experiential activities functions as a strategic filtering step. The resulting empirical data serve two main purposes. First, they allow researchers to identify, with reasonable precision, an optimal zone of interest that can guide the design of enrichment topics aligned with the preferences of the majority, which is likely important for sustaining intrinsic motivation over time. Second, the survey provides a critical basis for recognizing and selecting core individuals, often considered outliers, who demonstrate notably strong abilities across a range of domains. These individuals can then be assembled into cross-functional teams that appear better suited to addressing technically complex tasks rather than narrowly scoped or isolated problems.

4.1. Survey on Students' Interest

Based on the view of Usher and Barak (2020), diversity in background and gender within a group should not be seen as a problem. Instead, it can be a positive condition that likely supports creative and new solutions. The results in Table 2 reflect this idea clearly, as they challenge common gender stereotypes. While female participants demonstrated robust engagement in mechanical design, a significant gender gap persists in computational domains (AI/Robotics). This suggests that 'Design' acts as a gateway for female STEM participation, whereas coding remains a barrier.

This difference suggests that using a pre-diagnostic survey before forming research groups is a necessary methodological step. Such a survey helps teachers avoid personal assumptions or gender bias. More importantly, it allows them to identify students' real interests and strengths, which can then be combined to form complementary groups. For areas where interest from one gender is still limited—especially Robotics and AI among female students—the survey results provide a clear basis for planning bridge bootcamps that focus on basic skills. Filling these skill gaps before the main project begins not only reduces technical differences but also helps students feel more confident. As a result, all members, regardless of gender or initial interest, are more willing to work together and share their ideas.

Through this approach, diversity becomes more than just a difference between individuals. It turns into a shared source of ability. This is especially important for projects that require interdisciplinary work and innovative thinking, such as those prepared for science and engineering competitions like VISEF and ISEF.

4.2. An Illustrative Case Study of the INSPIRE Framework in Practice

4.2.1. Project Description

Literature review shows that most authors use Arduino as the central control board combined with ultrasonic or infrared sensors to detect

Table 2. Survey results on students' interests

	Mechanical design and manufacturing	Programming and intelligent systems	Robotics and AI integration
Male students	70	52	78
Female students	82	35	33

the status of parking lots (Nagarjuna *et al*., 2024). These studies generally fall into two main directions. The first focuses on enhancing customer experience, such as reservation systems and electronic payments (Sabbea *et al*., 2018); RFID card authentication and payment (Kabir *et al*., 2019) or integrating AI to detect and resolve improper parking issues *(Laaouafy et al*., 2024). The second direction aims to expand the functionalities of parking lots, such as integrating XBee modules to display information on device interfaces (Kepuska & Alshamsi, 2016) or incorporating sensors for measuring temperature, humidity, and toxic gases (Mamun *et al*., 2025). Additionally, leveraging models of autonomous vehicle control is seen as a promising approach. For example, Prongnuch and Sitjongsataporn (2020) successfully experimented with voice-controlled vehicle models using traditional voice recognition methods, without relying on advanced AI training techniques. To evaluate the efficacy of the INSPIRE framework, a Standardized Reference Task (SRT) was selected: the Voice-Controlled Automated Parking System. This topic was chosen not for inherent technical novelty, but because it serves as a canonical engineering challenge involving multiple integration points (mechanical structure, sensor fusion, and AI-driven control). By utilizing a well-documented engineering problem, the study isolates the process-dependent variables—specifically, how students navigate the transition from passive assembly to active research methodology under the INSPIRE protocol.

Project requirements: Simulate a modern car parking and retrieval system, where pallets act as transport devices that deliver cars to specific storage spots or move cars out on demand.

Students' research tasks:

- Design the hardware based on Arduino Uno R3 and components such as a breadboard, jumper wires, infrared sensors, an LCD screen, and a servo motor to control the barrier gate.

- Program the automation control for the hardware.

- Develop an AI voice recognition model to control the pallet's automatic movement along pre-marked lines (line-following).

Project evaluation criteria: Judges will evaluate the SRT based on five criteria, with a maximum total score of 100 points distributed as follows: Scientific rigor of the SRT (10 points), Design and research methodology (15 points), Fabrication and testing (20 points), Creativity (20 points), Poster presentation (10 points), and Responses to questions and defence (25 points).

4.2.2. Organizing Technical Research Projects Using the INSPIRE Process

Stage 1: Identify the problem and review research

Teachers guide students to identify current, unresolved issues that hold value for the community. At the same time, they provide reputable academic resources and instruct students on how to familiarize themselves with scientific citation and literature review using AI tools such as NotebookLM, Elicit, and Connected Papers. Next, students apply creative thinking techniques - like focused object analysis, morphological analysis, and TRIZ - to develop innovative solutions, culminating in the completion of a functional flowchart outlining the principle of operation.

Stage 2: Nominate a solution design framework

Systematize the specific tasks involved in the solution, select appropriate devices or components, and outline the sequence of practical verification activities needed to complete the solution - from individual parts to the overall system.

Stage 3: Sketch a visual model

Complete the design drawings—including the shape, dimensions, and physical structure of the solution—based on the design framework approved by the teacher and, if available, experts. From this stage, students are encouraged to use Gantt charts to manage project timelines; any adjustments must be fully updated and documented.

Stage 4: Prototype

Students are required to design an accurate electrical circuit diagram that clearly shows connections and the installation of devices/

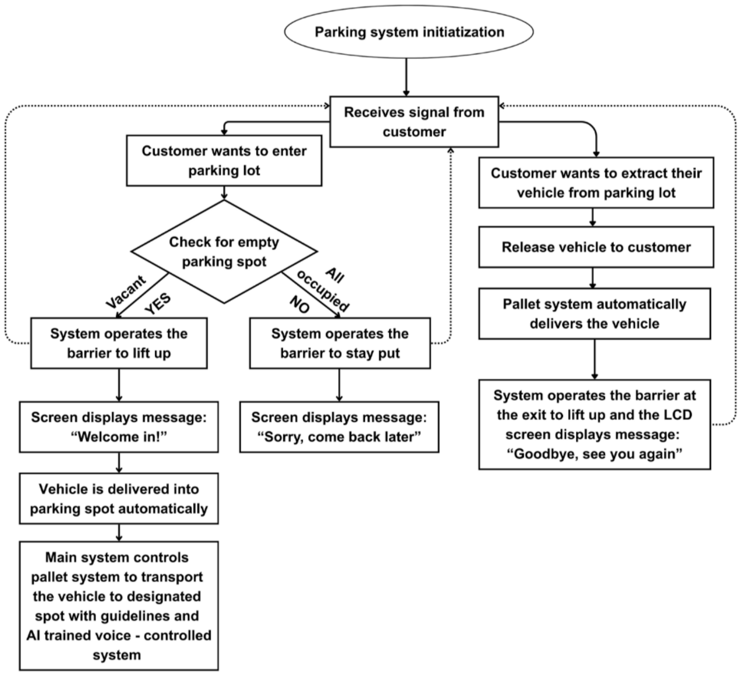

Figure 2. Operational flowchart

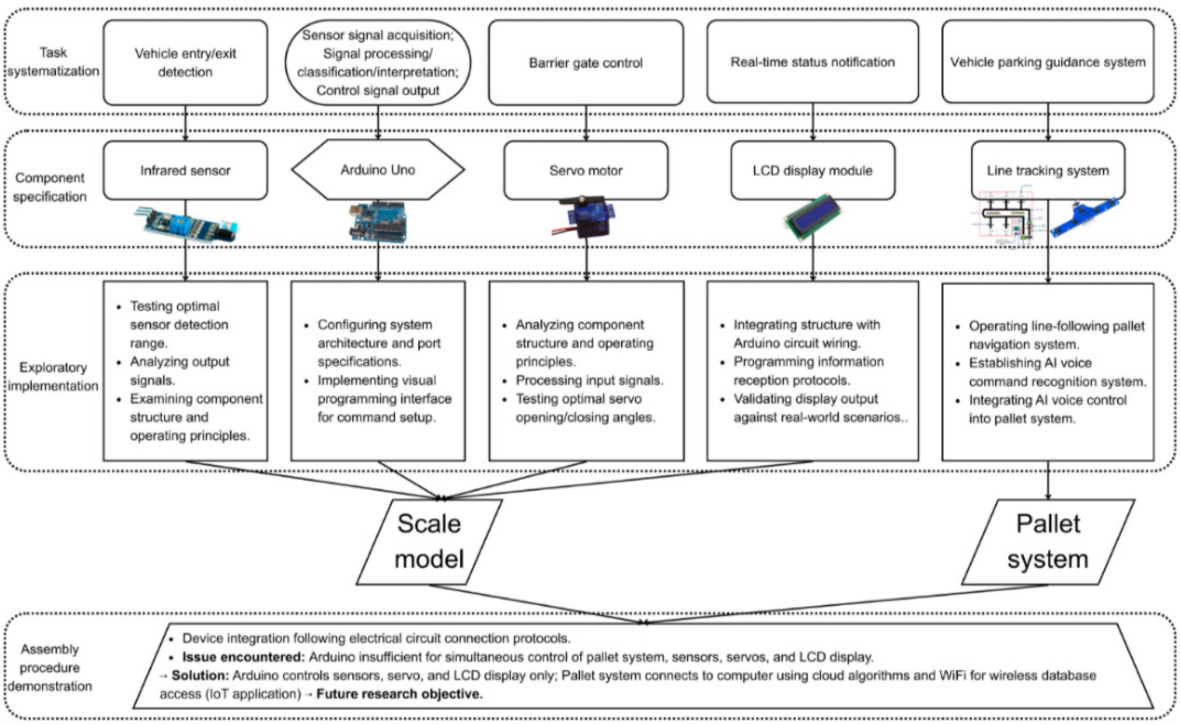

Figure 3. Framework for engineering product design

components, while ensuring compatibility with the design drawings. The hardware prototype is built based on this diagram. Software programming is carried out using a block-based drag-and-drop interface in Vietnamese, ensuring compatibility with the flowchart developed in Stage 1.

<u>*Stage 5:*</u> Iterate test and improve

Operate the product under various conditions to evaluate its effectiveness and suggest directions for further development. All testing results - whether successful or not - must be thoroughly documented in a detailed experience report, including specific recommendations for

https://doi.org/10.15625/2615-8965/22510401

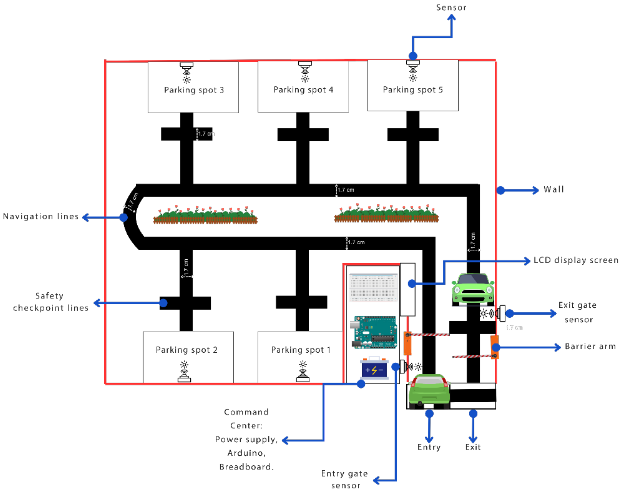

Figure 4. Layout design diagram

adjustments.

Stage 6: Reveal the Results through posters or other multimedia

Leverage images of the product and multimedia resources gathered during the research process - especially from the testing phase - to design a scientific poster. The poster

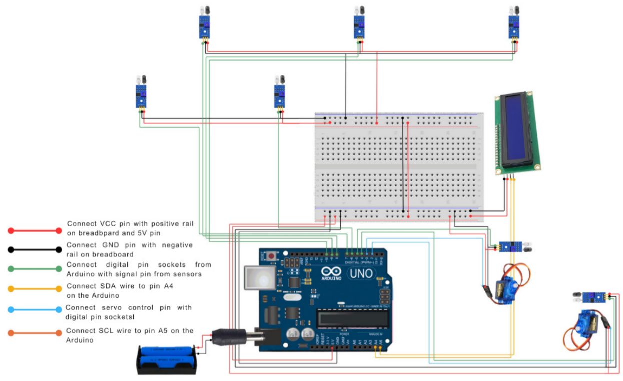

Figure 5.Arduino circuit design drawing

should be presented in English, using precise and concise technical language; it must include full citations of references and comply with the size and formatting guidelines of the VISEF/ISEF competitions.

Stage 7: Explain and defend

Students explain their project by presenting posters, demonstrating their products, and responding to judges' questions. They need to clearly articulate the role of STEAM components

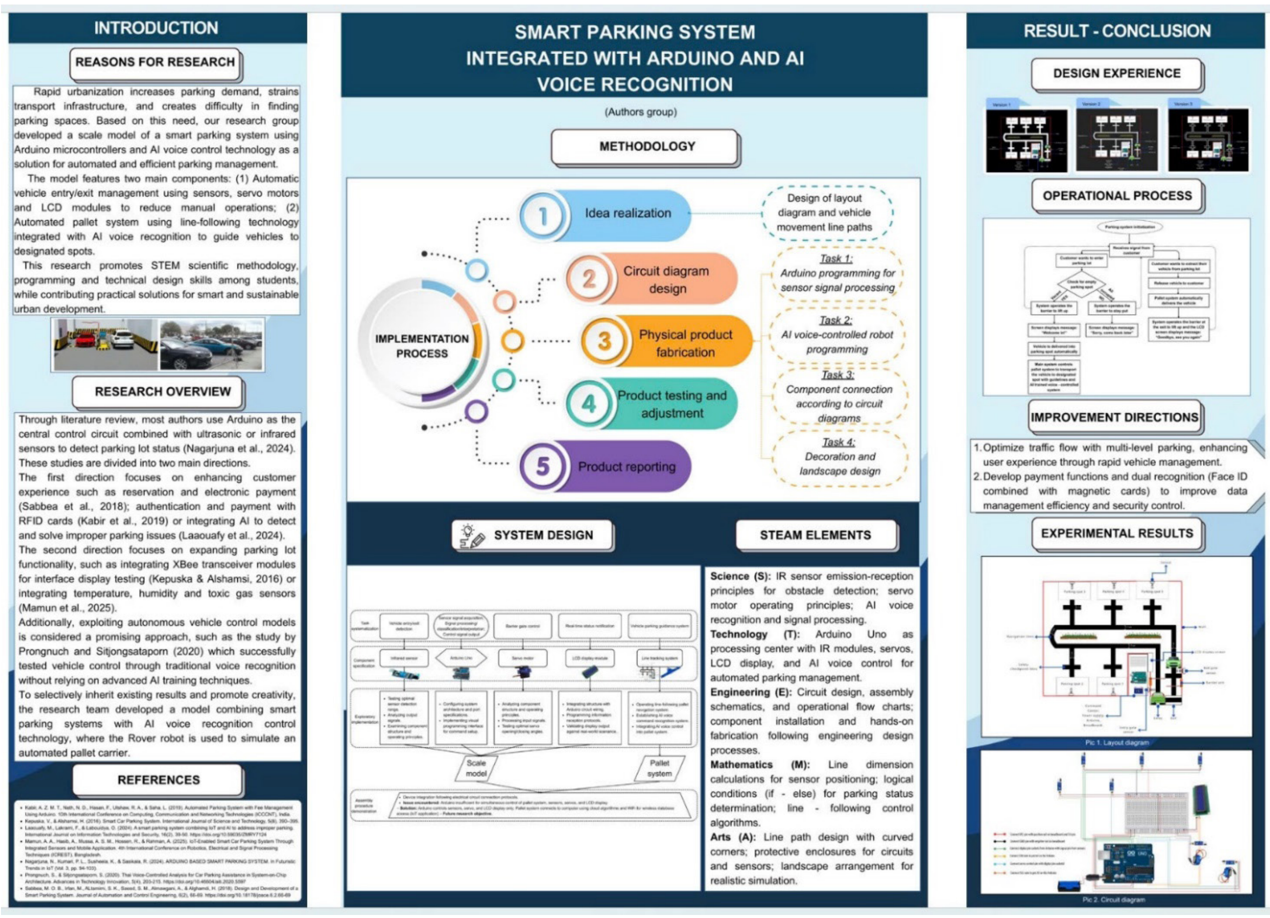

Figure 6. Research poster

https://doi.org/10.15625/2615-8965/22510401

within the project, linking them to the curriculum or STEM activities they have experienced. Their arguments should be honest, convincing, and supported by evaluation evidence; they must also acknowledge limitations and propose directions for future development. At the same time, students are expected to clearly demonstrate their individual contributions, understanding, and the division of tasks among team members.

4.3. Analysis of the Research Results

The core value of this research does not rest solely on confirming the apparent effectiveness of the INSPIRE framework. It also lies in clarifying the underlying psycho-pedagogical mechanisms that may have supported the transformation from passive learners to a mindset resembling that of active researchers. By placing thick qualitative data from observations and in-depth interviews alongside large-scale quantitative studies conducted globally, we observed a convergence of two core themes. Within this convergence, statistical evidence appears to function as a means of substantiating the real experiences reported by both students and teachers, rather than replacing or abstracting them.

Theme A: Human-Led Co-Creation with AI

A. Prompting Skills and Critical Thinking

Effective AI use depends largely on how users define its role - whether as an assistant, advisor, creative partner, or simply an information retrieval tool. Prompt crafting helps reveal thinking gaps and encourages deeper learning and enhances metacognitive reflection. Even free versions of AI can adequately meet users' needs, if there is a thoughtful strategy in place to avoid overreliance, fabrication errors, and biases.

"AI nowadays is quite advanced; it can even mimic user preferences, what they call Personalization AI. So, it's all the more important to use well-structured prompts, making it self-critique through multiple rounds or explaining reasoning step-by-step. Another way is to perform deep research by checking indexes carefully," - Teacher 01.

"I have registered multiple accounts and use various AI tools. By signing up with my personal email, I can access them both on my phone and laptop, and it works well," - Teacher 02.

"To prevent hallucinations, we require the AI to answer 'I don't know' if it cannot find reliable information," - Teacher 03.

"Sometimes I ask several AI systems to debate among themselves to find the most accurate answer, demanding evidence from different perspectives," - Manager 03.

Classroom practice fully matched the quantitative results reported by Sawalha *et al.* (2024), which indicate that active interaction—through Single Reformulated Prompting, Multiple-Question Prompting, and debating with AI—and prompt refinement, rather than passive copying (namely Single Copy-and-Paste), are key factors in achieving high accuracy when using GenAI. Students in the SRT also appeared to form this strategy naturally on their own:

"I actually ask the AI to write prompts for me first, then I review and paste them back," - Student 03.

"My whole group debates with the AI together," - Student 04.

"Writing prompts is essentially restating your own task in detail, along with the specific requirements to be met," - Manager 02.

"I've noticed that students begin to think more deeply about how they learn and their ability to synthesize ideas seems to improve once they start researching with AI," - Teacher 04.

B. Trust in AI and the Role of the Teacher

Trust in AI varies distinctly across different groups of students. Some appreciate the fresh writing style and novel suggestions AI offers, which makes them more inclined to use it regularly. On the other hand, some students remain sceptical of AI's capabilities, especially after repeatedly encountering inaccurate or misleading responses, leading to less frequent use. Research findings also highlight that while AI can provide a wealth of information, its knowledge tends to be general and lacks depth in specific subjects or fields. Consequently, AI cannot replace the essential pedagogical role of teachers in guiding and shaping strategic learning directions.

"Well, it doesn't remember the conversation; after a while, AI starts giving all kinds of mixed-up answers, Sir," - Student 01.

"I don't like the whole 'AI First' approach. It doesn't even understand what I need. If I have to spend time writing prompts, I'd rather just ask my teacher for guidance. My teacher always knows the answers and is the most reliable," - Student 02.

"When I'm stuck, I just try to think harder and find the mistake myself rather than asking AI. I don't trust it much, and it can't fix the model for me anyway," - Student 04.

The responses of Student 01, Student 02, and Student 04 may in fact indicate a positive outcome. This does not merely reflect an emotional preference for the teacher, but rather reflects a cognitive defence mechanism, in which students select the teacher as an epistemic anchor to evaluate hypotheses generated by AI. In a quantitative survey conducted by Lee *et al*. (2025) with 319 participants, an inverse correlation was observed the greater the absolute trust placed in AI, the lower the engagement in critical thinking. Conversely, individuals with higher confidence in their own abilities—such as Student 02, who trusted both the teacher and their own judgment—tended to retain stronger epistemic control. Accordingly, within the INSPIRE framework, AI does not replace the teacher; rather, it underscores the teacher's role as an arbiter of knowledge.

C. The Effectiveness of Co-Creation

The rapid rise of AI compels us to rethink the concept of creativity and the fine line between individual creativity and creativity supported by technology. The crucial role of humans lies in decision-making and leaving a unique mark. Only by staying fully aware throughout the entire interaction—through dialogue, debate, and critique with AI—can students turn technology into a launchpad for their creative confidence, rather than losing themselves and becoming merely guided followers.

"AI is helpless when it comes to drag-and-drop programming like this, though it might suggest some ideas," - Teacher 02.

"The AI took me way off track, Sir. At first, the reading was engaging, but when I asked it about coding AI models, it started leading me into IoT and self-driving cars and all sorts of stuff. [Laughter] I actually got tricked into spending hours on that. It was so frustrating—after all that, I still couldn't fix the problem," - Student 03.

This data accurately reflects the nature of the Human-AI collaborative model demonstrated by Vaccaro *et al*. (2024), showing that in creative tasks, the combination of human and AI contributions produces performance gains that surpass those achieved by humans or AI working alone. AI offers novelty, while humans provide assessments of feasibility. The failure of Student 03, who relied unquestioningly on AI-generated code, illustrates the need for students to have a solid foundational knowledge in order to critically filter and evaluate information from AI.

"I only like doing things that come from our own ideas. That's what makes it authentic, Sir," - Student 02.

"One student asked me if they could enter a competition by simply building on AI-generated ideas, and whether that would count as being creative," - Manager 02.

Theme B: Impact-Driven Learning Ecosystem

A. Social Impact and Civic Responsibility

Robotics and AI projects often raise ethical questions that supervising teachers had not considered. Students begin to view their work not merely as assignments or final projects but as means to create social impact, spanning from environmental concerns and community welfare to broader humanitarian values. In this context, interdisciplinary knowledge such as sociology and law finds its way into the learning process, enriching students' experiences and fostering qualities like global citizenship and responsibility.

"Just recently, Student 04 messaged me asking, 'If an automated system fails and causes an accident, who is responsible?' It was such a great question. Thanks to that, someone like me - who comes from a social science background - finally got a foothold in the STEM domain," - Teacher 04.

"Oh wow, I only just realized that electronic products like these actually have legal regulations involved. It was honestly surprising, Sir," - Student 01.

This development is consistent with the quantitative findings of Moffit (2024), which indicate that students participating in social impact projects are 15.4 times more likely to report higher learning motivation compared with those engaged in purely theoretical projects. The practical significance of these projects appears to motivate students to proactively expand their learning environments beyond the confines of the classroom:

"There's full support, of course. The teacher even came to ask me - students now want to do external interviews, parents have signed consent forms, and are even driving them there. It's surprising how proactive students have become," - Manager 01.

"I thought it was just talk, but turns out people really need it. My dad also supports going out to do surveys," - Student 04.

B. The Productive Failure Mechanism

Scientific research no longer remains confined to the traditional teacher-student relationship; instead, it expands into a multidimensional social network involving experts, technology developers, and anyone with relevant experience or appropriate learning resources. Notably, the impact from students goes beyond mere participation - they actively contribute to reshaping the learning ecosystem itself. Students take the initiative to propose changes in group organization, reframe problems from their unique perspectives (reverse inquiry), and consult with teachers to collaboratively redesign the research implementation process. The observational data reveal a surprisingly resilient attitude among students in the face of repeated technical errors. Rather than becoming discouraged, they seemed to treat these setbacks as part of the learning process:

"We spent about 40 days on this project and failed in nearly 20 different ways. But no one felt discouraged. It's our project, after all. The important thing is we understood why we failed and managed to fix it ourselves," - Student 01.

"The video library package from that Russian guy's channel runs well and is compatible on many laptops," - Student 03.

This phenomenon vividly illustrates the theory of Productive Failure (Kapur, 2025), quantitative studies have shown that students who first encounter challenges and experience what might be called "productive failure" in problem-solving—before receiving formal guidance through direct instruction—tend to develop a deeper conceptual understanding and stronger transfer skills than those who are taught the theory from the start. The deliberate playfulness that teachers observe in the classroom seems to reflect design thinking in action, showing how creative problem-solving actually unfolds in practice.

"The manufacturer never forbade making a model with a black base and white stripes, so I wanted to experiment and see what happens. Maybe the sensor would still work," - Student 02.

"Watch closely - those who are willing to learn but also to experiment tend to be confident and clever. They dare to break things because they know how to fix them. Teaching that kind of class is less exhausting, and learning is more fun too," - Teacher 04.

C. Extended learning network

Solving problems is no longer a task imposed from outside but becomes a natural need that arises during the prototyping process. Students understand that failure is not an endpoint but a necessary pause, allowing time to reflect and reconsider. This reflects 'productive deviation', where students test system limits through unauthorized but inquisitive experimentation. Sometimes, students deliberately make mistakes to observe reactions, "tease" their teachers, or turn situations that require fixing into opportunities to launch their own bold ideas.

"They teach themselves coding on YouTube, using foreign channels—pretty impressive. They even know how to install Chrome Extensions and stuff, like Voiceping to use voice commands," - Teacher 01.

"We failed a lot. It was almost frustrating, but our whole group had to think hard, ask everyone we could, reread the materials from the start, and try out every idea as soon as it came up," - Student 03.

This initiative highlights the effectiveness of the project-based learning model, which, according to the meta-analysis by Zhang and Ma (2023), has a strong impact on learners' autonomy.

"Responsibility lies with everyone, including the school leadership. There needs to be a system to empower students after the project - this journey is just beginning and doesn't end here," - Manager 03.

In summary, the study's results suggest that a project's success is measured not only by awards or tangible products, but by the development of a researcher identity in students: the ability to question technology critically, the willingness to embrace failure, and the habit of reflecting on the social impact of the creations they produce.

5. Conclusions

The INSPIRE protocol successfully transformed a STEM experience into a technical research project that meets VISEF/ISEF standards. It highlights two critical factors - 'Human-Led Co-Creation with AI' and an 'Impact-Driven Learning Ecosystem' - that must be emphasized to ensure the research project is carried out in the right spirit and delivers value both to the community and to the students themselves. To improve effectiveness and scalability, further testing is needed across a wider range of topics, participant groups, and learning environments. Notably, as AI is expected to surge even further in the future, subsequent studies need to focus on developing students' skills in multi-criteria decision-making and multi-objective optimization when using AI, in order to maintain students' active leadership in scientific research.

Local education authorities should encourage greater collaboration between schools and experts, particularly those from research centres or technology businesses. The goal is to establish a free research consultation channel, create a detailed checklist to guide research work and product development for competitions, and set up an affordable innovation space that ensures access to emerging technologies.

References

Anđić, B., Maričić, M., Mumcu, F., Prodromou, T., Leoste, J., Saimon, M., & Lavicza, Z. (2024). Direct and indirect instruction in educational robotics: a comparative study of task performance per cognitive level and student perception. *Smart Learning Environments*, *11*(1), 12. https://doi.org/10.1186/s40561-024-00298-6

Chen, P.-H., Huang, Y.-M., Wu, T.-T., & Lee, H.-Y. (2025). Coding Error-Based Reflective Learning with ChatGPT: A Study on Higher-order Thinking Skills in Programming Education. Proceedings of the 6th International Conference on Modern Educational Technology, https://doi.org/10.1145/3729434.3729435

Hong, B. V., Phuong, P. N. T., & Tiep, N. Q. (2023). Thực trạng dạy học STEM cho học sinh phổ thông tại Thành phố Hồ Chí Minh [Current status of STEM teaching for high school students in Ho Chi Minh City]. *Vietnam Journal of Education*, *23*(03), 31-35. https://tcgd.tapchigiaoduc.edu.vn/index.php/tapchi/article/view/640

Jia, L., Jalaludin, N. A., & Rasul, M. S. (2023). Design Thinking and Project-Based Learning (DT-PBL): A Review of the Literature. *International Journal of Learning, Teaching and Educational Research*, *22*(08). https://doi.org/10.26803/ijlter.22.8.20

Kabir, A. Z. M. T., Nath, N. D., Hasan, F., Utshaw, R. A., & Saha, L. (2019). Automated Parking System with Fee Management Using Arduino. 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT), India.

Kapur, M. (2025). *Productive failure: Unlocking deeper learning through the science of failing.* John Wiley & Sons.

Kepuska, V., & Alshamsi, H. (2016). Smart Car Parking System. *International Journal of Science and Technology*, *5*(8), 390–395. https://doi.org/https://doi.org/10.1016/j.tate.2022.103956

King-Sears, M. E., Stefanidis, A., Evmenova, A. S., Rao, K., Mergen, R. L., Owen, L. S., & Strimel, M. M. (2023). Achievement of learners receiving UDL instruction: A meta-analysis. *Teaching and Teacher Education, 122,* 1-15. https://doi.org/10.1016/j.tate.2022.103956

Kosmas, P., Nisiforou, E. A., Kounnapi, E., Sophocleous, S., & Theophanous, G. (2025). Integrating artificial intelligence in literacy lessons for elementary classrooms: a co-design approach. *Educational* *technology research and development*, *73*(4), 2589-2615. https://doi.org/10.1007/s11423-025-10492-z

Laaouafy, M., Lakrami, F., & Labouidya, O. (2024). A smart parking system combining IoT and AI to address improper parking. *International Journal on Information Technologies and Security*, *16*(2), 39-50. https://doi.org/10.59035/ZMRY7124

Lee, H.-P., Sarkar, A., Tankelevitch, L., Drosos, I., Rintel, S., Banks, R., & Wilson, N. (2025). The impact of generative AI on critical thinking: Self-reported reductions in cognitive effort and confidence effects from a survey of knowledge workers. In Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '25).

Lee, H.-Y., Chen, P.-H., Wang, W.-S., Huang, Y.-M., & Wu, T.-T. (2024). Empowering ChatGPT with guidance mechanism in blended learning: effect of self-regulated learning, higher-order thinking skills, and knowledge construction. *International Journal of Educational Technology in Higher Education*, *21*(1), 16. https://doi.org/10.1186/s41239-024-00447-4

Lin, C.-J., Lee, H.-Y., Wang, W.-S., Huang, Y.-M., & Wu, T.-T. (2025). Enhancing STEM collaboration through reflective strategies in the 6E learning model: insights from voice recognition analysis. *Education and Information Technologies*, *30*(4), 4251-4276. https://doi.org/10.1007/s10639-024-12957-9

Mamun, A. A., Hasib, A., Mussa, A. S. M., Hossen, R., & Rahman, A. (2025). IoT-Enabled Smart Car Parking System Through Integrated Sensors and Mobile Application. 4th International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST), Bangladesh.

Ministry of Education and Training. (2024). *Thông tư số 06/2024/TT-BGDĐT về ban hành Quy chế Cuộc thi nghiên cứu khoa học, kỹ thuật cấp quốc gia dành cho học sinh trung học cơ sở và trung học phổ thông [Circular No. 06/2024/TT-BGDĐT: Promulgating the Regulation on the National Science and Technology Research Competition for Secondary Students]*. Ha Noi. Retrieved from https://tulieuvankien.dangcongsan.vn/he-thong-van-ban/van-ban-quy-pham-phap-luat/thong-tu-so-062024tt-bgddt-ngay-10042024-cua-bo-giao-duc-va-dao-tao-ban-hanh-quy-che-cuoc-thi-nghien-cuu-khoa-hoc-ky-thuat-10382

Moffit, J. L. (2024). *Effect of Social Impact Project on Student Motivation, Engagement, and Achievement* [Doctor of Education (Ed.D.) Dissertation, Arkansas State University]. Jonesboro, Arkansas. https://arch.astate.edu/all-etd/17

Nagarjuna, N., Kumari, P. L., Susheela, K., & Sasikala, R. (2024). Arduino-based smart parking system. In *Futuristic Trends in IoT* (Vol. 3, pp. 94–103).

Nga, N. T., Muoi, H. P., Duc, N. M., Hien, P. T. T., Tam, T. N., Phung, N. Y., & Ngoc, T. T. (2022). *Thiết kế và tổ chức hoạt động trải nghiệm STEM/STEAM và nghiên cứu khoa học kĩ thuật ở trường phổ thông [Design and organization of STEM/STEAM experiential activities and technical scientific research in secondary schools]*. Nhà xuất bản Đại học Sư phạm Thành phố Hồ Chí Minh [Ho Chi Minh City University of Education Publishing House].

Ngan, L. H. M., Tu, N. T., Ngoc, M. T. K., Phuong, D. D., Thang, V. Q., & Bien, N. V. (2020). Một số yếu tố ảnh hưởng hứng thú đối với lĩnh vực Robotics của học sinh một số trường trung học cơ sở ở tại TP Hồ Chí Minh [Factors influencing students' interest in robotics among several lower secondary schools in Ho Chi Minh City]. *Ho Chi Minh City University of Education Journal of Science*, *17*(08), 1337-1350.

Nugraha, M. G., Kidman, G., & Tan, H. (2024). Interdisciplinary STEM education foundational concepts: Implementation for knowledge creation. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(10). https://doi.org/10.29333/ejmste/15471

Öndeş, R. N. (2025). Effects of STEM Practices on Students' Problem-Solving Skills: A Meta-Analysis. *International Journal of Education in Mathematics, Science and Technology*, *13*(2), 439-461. https://doi.org/10.46328/ijemst.4697

Phuong, P. N. T., Hong, B. V., Phuong, D. V., De, D. V., Trinh, N. T. T., & Tiep, N. Q. (2024). Nâng cao năng lực hướng dẫn nghiên cứu khoa học về giáo dục STEM cho giáo viên Trung học cơ sở: Thực trạng và một số biện pháp [Enhancing the capacity to guide STEM scientific research for lower secondary school teachers: Current status and some solutions]. *Vietnam Journal of Education*, *24*(Special Issue 8), 267-273.

Politburo. (2024). *Nghị quyết Số 57-NQ/TW về đột phá phát triển khoa học, công nghệ, đổi mới sáng tạo và chuyển đổi số quốc gia [Resolution No. 57-NQ/TW on breakthroughs in the development of science, technology, innovation, and national digital transformation]*. Ha Noi. Retrieved from https://tulieuvankien.dangcongsan.vn/he-thong-van-ban/van-ban-cua-dang/nghi-quyet-so-57-nqtw-ngay-22122024-cua-bo-chinh-tri-ve-dot-pha-phat-trien-khoa-hoc-cong-nghe-doi-moi-sang-tao-va-chuyen-11162

Politburo. (2025). *Nghị quyết Số 71-NQ/TW về đột phá phát triển giáo dục và đào tạo [Resolution No. 71-NQ/TW on breakthroughs in the development of education and training]*. Ha Noi. Retrieved from https://tulieuvankien.dangcongsan.vn/he-thong-van-ban/van-ban-cua-dang/nghi-quyet-so-71-nqtw-ngay-2282025-cua-bo-chinh-tri-ve-dot-pha-phat-trien-giao-duc-va-dao-tao-11771

Prongnuch, S., & Sitjongsataporn, S. (2020). Thai Voice-Controlled Analysis for Car Parking Assistance in System-on-Chip Architecture. *Advances in Technology Innovation*, *5*(4), 203-215. https://doi.org/10.46604/aiti.2020.5597

Sabbea, M. O. B., Irfan, M., ALtamimi, S. K., Saeed, S. M., Almawgani, A. H. M., & Alghamdi, H. (2018). Design and Development of a Smart Parking System. *Journal of Automation and Control Engineering*, *6*(2), 66-69. https://doi.org/10.18178/joace.6.2.66-69

Santos, P., El Aadmi, K., Calvera-Isabal, M., & Rodríguez, A. (2025). Fostering students' motivation and self-efficacy in science, technology, engineering, and design through design thinking and making in project-based learning: a gender-perspective study in primary education. *International Journal of Technology and Design Education*, *35*(4), 1293-1319. https://doi.org/10.1007/s10798-025-10001-6

Sawalha, G., Taj, I., & Shoufan, A. (2024). Analyzing student prompts and their effect on ChatGPT's performance. *Cogent Education*, *11*(1), 2397200. https://doi.org/10.1080/2331186X.2024.2397200

Society for Science. (2025). *International rules for pre-college science research: Guidelines for science and engineering fairs 2025-2026*. https://www.societyforscience.org/isef/international-rules/

Thach, L. N., Ho, H. T. T., Chuong, H. L. A., Huyen, V. T. T., Huan, L. D., Diem, C. T. T., Tri, L. H. M., Khuong, N. H., & Hau, N. T. (2024). *Hướng dẫn học sinh trung học nghiên cứu khoa học [A guide to scientific research for secondary school students]*. Nhà xuất bản Đại học Sư phạm Thành phố Hồ Chí Minh [Ho Chi Minh City University of Education Publishing House].

Usher, M., & Barak, M. (2020). Team diversity as a predictor of innovation in team projects of face-to-face and online learners. *Computers & Education*, *144*, 103702. https://doi.org/10.1016/j.compedu.2019.103702

Vaccaro, M., Almaatouq, A., & Malone, T. (2024). When combinations of humans and AI are useful: A systematic review and meta-analysis. *Nature Human Behaviour*, *8*(12), 2293-2303. https://doi.org/10.1038/s41562-024-02024-1

Wu, T.-T., Lee, H.-Y., Li, P.-H., Huang, C.-N., & Huang, Y.-M. (2024). Promoting Self-Regulation Progress and Knowledge Construction in Blended Learning via ChatGPT-Based Learning Aid. *Journal of Educational Computing Research*, *61*(8), 1539-1567. https://doi.org/10.1177/07356331231191125

Zhang, L., & Ma, Y. (2023). A study of the impact of project-based learning on student learning effects: a meta-analysis study. *Frontiers in Psychology*, *14*. https://doi.org/10.3389/fpsyg.2023.1202728