'INNOVATORS OF TOMORROW': EMERGING TRENDS IN PHYSICS-INSPIRED INNOVATIONS COMPETITION

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Abstract. Student innovation competitions are essential for developing the next generation of leaders in science and technology, especially as the Malaysian government continues to push for more development in the field of innovation. In conjunction to this, this study seeks to explore the emerging trends in physics-based innovations within the 'Innovators of Tomorrow' competition in Malaysia, focusing on how students apply physics principles to solve real-world challenges. Using qualitative content analysis, 41 physics-related projects from the competition (2023–2024) were analyzed to identify key themes and trends across various fields. The results indicate a strong emphasis on renewable energy solutions, material science, and robotics, reflecting both global and local needs for sustainable development and technological innovation. The findings highlight the crucial role of physics education in fostering student innovation and align with Malaysia's goals of becoming a knowledge-based, innovation-driven economy. Recommendations for enhancing the integration of physics in STEM education are provided, with a focus on preparing students for future advancements in science and technology.
Keywords: *emerging trends, Malaysia, physics, physics education, STEM education*

Introduction

In Malaysia, fostering innovation has been a key national priority (Liew and Teoh, 2022), as seen through numerous educational initiatives aimed at enhancing students' engagement with science, technology, engineering, and mathematics (STEM). As the Malaysian government continues to push for greater development in the field of innovation, student innovation competitions play a crucial role in cultivating future leaders in science and technology (Kim and Maloney, 2020). In Malaysia's Education Blueprint (2013-2025), an emphasis was placed on raising the quality of education and integrating STEM across all levels of schooling. This strategy aims to align Malaysia's educational outcomes with its vision of becoming a knowledge-based, innovation-driven economy. Trevissoi (2024) believes that Physics, being a fundamental part of the STEM curriculum, serves as a vital tool for students to explore the principles behind innovations in fields such as renewable energy, material science, and robotics. These fields are particularly important in Malaysia, where the drive toward sustainability and technological development is growing. The connection between physics and innovation has always been strong. Many groundbreaking technologies from electric power generation to cutting-edge quantum computing have their roots in the application of physical laws. In the context of Malaysia, physics-based innovations are key to addressing national challenges, such as increasing energy efficiency, developing sustainable technologies, and contributing to the country's Fourth Industrial Revolution (IR 4.0) goals (Kamel, 2022).

Despite the increasing emphasis on STEM education, there remains a need to better understand how students actually translate physics knowledge into innovative outputs

(Verawati and Nisrina, 2025). While curriculum documents highlight the importance of inquiry-based learning and higher-order thinking skills, Kotsis (2025) believed that limited empirical attention has been given to examining the nature of student-generated physics innovations in authentic competition settings. Investigating student projects provides valuable insight into how theoretical classroom knowledge is transformed into applied solutions, revealing both the strengths and gaps in current physics education practices. Student innovation competitions, such as the 'Innovators of Tomorrow', function as experiential learning platforms where learners engage in problem identification, prototype development, and solution testing. These environments encourage creativity, collaboration, and real-world application of scientific principles beyond textbook-based learning. By analyzing projects developed within this context, the present study seeks to uncover not only dominant thematic trends but also the extent to which physics principles are meaningfully integrated into practical designs. Such analysis can inform educators about the effectiveness of current pedagogical approaches in nurturing innovation-oriented thinking.

Furthermore, understanding emerging trends in physics-based innovations at the primary school level is particularly significant. Early exposure to applied scientific problem-solving may influence long-term interest in STEM pathways and future career aspirations (Khoso and Sahito, 2025). Identifying the types of challenges students prioritize, such as renewable energy, automation, or environmental sustainability can also reflect broader societal and national priorities. Therefore, this study contributes to ongoing discussions on strengthening physics education in Malaysia by providing empirical evidence on how young learners conceptualize and apply physics in innovation-driven contexts. The purpose of this study is to explore emerging trends in physics-based innovations within the 'Innovators of Tomorrow' competition. The 'Innovators of Tomorrow' competition provides a platform for students to showcase their creativity and problem-solving skills through innovative projects across various fields, including science, technology, and engineering. The central question driving this research is: What are the emerging trends in physics-inspired innovations within the 'Innovators of Tomorrow' competition, specifically in the Malaysian context? This study will provide insight into the evolving role of physics in student innovation and highlight the importance of fostering a deep understanding of physics concepts in education.

Literature review

Physics has been a cornerstone of technological advancement throughout history. Innovations in energy production, material development, and information technology all rely on the application of physical laws. For example, Faraday's laws of electromagnetism led to the development of electric motors, while thermodynamics has paved the way for advancements in energy efficiency and mechanical systems. The ability of physics to provide explanations for natural phenomena allows scientists and innovators to create technologies that address modern-day challenges, such as climate change and energy scarcity. In the context of student innovation competitions, physics often serves as a foundation for problem-solving, where students take concepts from their classrooms and apply them in practical ways. According to Taherdoost (2024), the transition from theoretical knowledge to applied innovation is a critical aspect of effective STEM education, with physics often acting as the linchpin for engineering and technology-focused projects. Dziob et al. (2022) highlight the importance of

competitions as spaces where students experiment with physics principles to design projects that address both everyday challenges and global issues.

Education systems around the world recognize the value of applying theoretical knowledge to real-world problems. Innovation competitions provide an opportunity for students to take what they have learned in physics classes and use it in practical, often interdisciplinary, projects. According to Saldo and Walag (2021), such competitions promote deeper learning by requiring students to engage in project-based learning (PBL), where they apply concepts from subjects like physics to solve complex problems. In physics-based innovations, competitions act as testing grounds for ideas related to mechanics, electromagnetism, quantum theory, and thermodynamics, among other branches. Yanti and Rahmad (2023) found that students who participated in innovation competitions showed improved problem-solving skills and were better able to synthesize knowledge from multiple areas of physics. Additionally, the competitive nature of these events encourages students to push the boundaries of creativity and explore emerging fields such as quantum technology and sustainable energy solutions.

In addition to fostering interdisciplinary integration, innovation competitions also align with constructivist perspectives of learning, where knowledge is actively constructed through experience and reflection. Within physics education, constructivist approaches emphasize experimentation, inquiry, and conceptual restructuring as students confront real-world problems (Karwasz and Wyborska, 2024). Competitions provide an authentic context in which misconceptions can be challenged and refined through iterative design and testing. This experiential engagement deepens conceptual understanding by moving students beyond rote memorization toward meaningful application of physical principles in dynamic contexts. Moreover, the growing emphasis on sustainability and green technologies in student competitions reflects broader global and national policy priorities. As nations strive to meet environmental targets and transition toward renewable energy systems, educational platforms are increasingly seen as catalysts for cultivating environmentally literate citizens. Physics plays a critical role in this transition, particularly in areas such as energy transformation, material efficiency, and climate-related technologies. By embedding sustainability themes within innovation competitions, students are encouraged to connect scientific knowledge with ethical responsibility and long-term environmental stewardship. This alignment strengthens the relevance of physics education within contemporary societal discourse.

In accordance with Siddiqui (2025)'s findings, digital transformation and the rise of Industry 4.0 have further amplified the importance of physics-informed innovation. Emerging fields such as artificial intelligence, automation, smart systems, and advanced materials all rest upon foundational physical concepts. Competitions that incorporate robotics, sensor technologies, and data-driven systems expose students to the technological realities of the modern workforce. Pombo (2025) believed that such exposure not only enhances technical competence but also develops adaptability and forward-thinking mindsets. In this way, physics-based innovation competitions contribute to preparing learners for participation in rapidly evolving scientific and industrial landscapes, reinforcing the strategic importance of strengthening physics education at early stages of schooling. Competitions like the 'Innovators of Tomorrow' not only foster creativity but also strengthen participants' skills in STEM (Science, Technology, Engineering, and Mathematics) disciplines. These competitions provide an environment where theoretical knowledge is tested and refined through hands-on experience. Research underscores the role of physics competitions in improving

students' understanding of scientific inquiry, experimentation, and critical thinking, all of which are essential for innovation. These competitions serve as a bridge between classroom learning and the real-world application of STEM skills, allowing students to apply scientific methods in a controlled but competitive environment. Moreover, the integration of physics into innovation competitions has led to the emergence of trends in fields such as energy efficiency, robotics, and materials science. By providing students with the tools to approach problem-solving from a physics-oriented perspective, competitions foster a deeper engagement with the subject, encouraging not only academic success but also future careers in scientific research and technology development.

Beyond their cognitive benefits, innovation competitions also contribute to the development of soft skills that are closely linked to success in STEM fields. Participation in physics-based projects often requires teamwork, communication, time management, and iterative design thinking (Ha, 2024). These competencies are cultivated as students collaborate to refine prototypes, interpret experimental data, and present their findings to judges and peers. Such experiences mirror authentic scientific practice, where experimentation, revision, and peer evaluation are integral to progress. Consequently, Aithal and Maiya (2023) believed that competitions function not only as academic platforms but also as training grounds for professional scientific engagement. Recent literature also emphasizes the importance of early exposure to applied physics in shaping long-term interest in STEM careers. When students are given opportunities to experiment with real-world challenges, such as renewable energy systems or automation technologies, they are more likely to perceive physics as relevant and meaningful rather than abstract or difficult (Maftunzada, 2024). This relevance enhances intrinsic motivation and promotes sustained engagement with scientific inquiry. By contextualizing physics within pressing global issues such as sustainability and technological advancement, competitions help reposition the subject as dynamic and socially impactful, thereby countering declining interest often observed in traditional classroom settings.

Furthermore, the interdisciplinary nature of innovation competitions reflects the evolving landscape of contemporary science and technology. Modern challenges rarely fall within the boundaries of a single discipline; instead, they require integration across physics, engineering, environmental science, and digital technologies (Klein, 2023). Competitions that encourage cross-disciplinary thinking allow students to synthesize knowledge and apply physics principles in conjunction with coding, design, and environmental analysis. This integrative approach aligns with global educational reforms advocating for 21st-century competencies, including critical thinking, creativity, and complex problem-solving (Kumar and Prajapati, 2025). As such, physics-centered innovation competitions serve as microcosms of real-world scientific ecosystems, preparing students to navigate and contribute to increasingly interconnected technological domains.

Materials and Methods

This study employed a qualitative content analysis approach to identify and explore emerging trends in physics-based innovations from the 'Innovators of Tomorrow' competition in Malaysia. The competition data, comprising student project descriptions, presentations, and competition outcomes, will be systematically analyzed to categorize

the types of physics concepts and principles applied in these innovations. This method allows for a detailed understanding of how students engage with physics and how these engagements reflect broader trends in the field of physics-based innovation. Data for this research were sourced from the 'Innovators of Tomorrow' competition archives, which include project submissions, judges' feedback, and any available supplementary materials (such as prototypes or presentations). The sample includes the data from the last 2 editions of the 'Innovators of Tomorrow' competition (2023-2024). A total of 41 physics-based projects were analyzed. These projects were selected based on clear evidence of the application of physics concepts, such as mechanics, thermodynamics, electromagnetism, or quantum physics. The participants are all primary school students in the area of Kuala Lumpur and Klang Valley, Malaysia. Once the data is collected, each project is reviewed and categorized thematically based on their application fields, such as renewable energy, robotics, environmental physics, and sustainable technologies. After categorization, a thematic analysis will be conducted to identify common patterns and emerging trends across the projects. These themes will focus on the types of physics applications most frequently utilized and the innovation's impact on real-world challenges, such as energy efficiency or environmental sustainability.

To enhance analytical rigor, the qualitative content analysis was conducted using a systematic coding procedure. First, all project documents were read repeatedly to achieve data familiarization. An initial open coding process was then carried out to identify explicit references to physics concepts, innovation purposes, and real-world problem alignment. These preliminary codes were subsequently grouped into broader thematic categories reflecting both disciplinary focus and application domains. A coding framework was developed iteratively to ensure consistency in classification. To strengthen credibility, the coding scheme was reviewed and refined through peer discussion, and discrepancies in categorization were resolved through consensus. In addition, analytical attention was given not only to the presence of physics concepts but also to the depth of conceptual application and innovation sophistication. Projects were examined for evidence of conceptual accuracy, integration of multiple physics principles, feasibility of design, and relevance to identified societal challenges. Judges' feedback and competition outcomes were used as supplementary data to triangulate interpretations regarding innovation quality and practical significance. This multi-source approach enhances trustworthiness by reducing reliance on a single data type and supports a more comprehensive understanding of how primary school students engage with physics in authentic innovation contexts.

Results and Discussion

This section presents the key findings of the study based on the analysis of 41 student projects from the 'Innovators of Tomorrow' competition. The projects were categorized into four main areas: renewable energy, robotics, environmental physics, and sustainable technologies. Each category reflects the use of physics principles in innovative ways to address real-world challenges. The analysis revealed a strong emphasis on renewable energy, with several student projects focusing on creating sustainable energy solutions. Additionally, a project explored unconventional energy sources, investigating how electricity from lightning could be captured and utilized. The data proven, aligned with Yanti and Rahmad (2023) indicates that students are highly aware of the need for alternative energy sources, aligning with Malaysia's commitment

to sustainability and green energy initiatives. The projects in this category reflect a deep understanding of energy conservation, thermodynamics, and the physics behind energy transformation processes. The analysis of these projects reveals several key trends, which are: (a) Increasing Focus on Renewable Energy. Many projects, particularly in the renewable energy category, focused on creating more efficient and accessible clean energy sources. Solar power and biomass were prominent themes, indicating student awareness of Malaysia's green energy initiatives. The focus on renewable energy within the competition underscores a growing recognition of the urgent need for sustainable energy solutions. This trend is aligned with Malaysia's strategic goals to enhance its renewable energy sector as part of its commitment to the Paris Agreement and its national policies on green energy, according to Kim and Maloney (2020). The prominence of solar and biomass energy solutions in student projects reflects an understanding of the principles of thermodynamics and energy transfer, suggesting that students are not only familiar with these concepts but are also capable of applying them to create practical solutions. The innovative approaches seen in these projects could contribute to Malaysia's energy transition and offer scalable solutions for rural and urban areas alike.

(b) Rise of Automation through Robotics. Projects related to robotics showcased students' interest in automating processes, from parcel sorting to household chores. This reflects a trend towards the use of robotics for improving efficiency in both industrial and everyday contexts. These projects reveal an increasing trend towards integrating robotics into everyday processes, which is consistent with the global shift towards automation in both industrial and personal contexts. Taherdoost (2024) believed that by incorporating principles of kinematics, dynamics, and control systems, students are bridging theoretical knowledge with practical applications. This trend highlights the importance of hands-on experiences in robotics education, where students can experiment with real-world problems and develop solutions that could potentially be implemented in various sectors. (c) Environmental Consciousness. Environmental physics projects addressed key issues such as air and water quality, waste management, and disaster mitigation. This indicates a growing awareness among students of the need to use physics to solve environmental problems. These projects also indicate a sophisticated understanding of how physical principles can be used to design systems that have a tangible impact on environmental sustainability. For instance, innovations in waste management and flood control show how students are applying concepts like fluid dynamics and thermodynamics to solve pressing environmental issues. This aligns with Malaysia's efforts to promote sustainable development and manage environmental resources effectively. (d) Sustainable Product Development. The sustainable technologies category revealed innovative approaches to creating eco-friendly products, from pest control solutions to educational tools. This trend aligns with Malaysia's broader goal of promoting sustainability in all sectors. These innovations reflect a broader trend towards creating products that are both eco-friendly and functional, supporting Malaysia's goals of achieving a more sustainable economy. The diversity of projects in this category, from educational tools to pest control solutions, highlights the versatility of physics in creating sustainable products. The focus on integrating sustainability into various aspects of product design and functionality demonstrates a growing awareness among students of the need to consider environmental factors in technological development.

Beyond these four thematic categories, the findings also suggest an encouraging level of interdisciplinary integration among the students. Many projects did not rely solely on isolated physics concepts but combined principles from thermodynamics, electromagnetism, mechanics, and environmental science to propose holistic solutions. This indicates that students are beginning to view physics not merely as abstract theory, but as a problem-solving framework applicable across domains. Such integration reflects higher-order thinking skills, particularly analysis, synthesis, and application, which are essential for developing future-ready innovators capable of addressing complex societal challenges. Another notable pattern emerging from the analysis is the orientation toward community-based and context-responsive innovation. Several projects appeared to be inspired by local issues, such as flood mitigation, waste management in residential areas, and access to affordable energy solutions. This contextual grounding suggests that students are not only aware of global sustainability agendas but are also attentive to immediate community needs. The ability to connect physics concepts with real-life local challenges demonstrates meaningful learning, where theoretical knowledge is translated into socially relevant applications. This aligns with current educational aspirations to produce socially responsible graduates who can contribute directly to national development priorities.

Furthermore, the overall quality and diversity of the projects reflect the effectiveness of experiential and competition-based learning environments in stimulating creativity and innovation. The "Innovators of Tomorrow" competition appears to provide a platform that encourages inquiry, experimentation, and design thinking. By engaging in project-based exploration, students are given opportunities to test hypotheses, refine prototypes, and evaluate feasibility processes that mirror authentic scientific practice. This suggests that structured innovation platforms can play a significant role in strengthening STEM engagement and nurturing a generation of learners who are not only conceptually competent in physics but also confident in applying their knowledge toward sustainable and technological advancement.

Conclusion

The study highlights the significant role of physics in driving innovation across various fields. The projects presented by students reflect a strong commitment to addressing contemporary challenges through renewable energy solutions, robotics, environmental physics, and sustainable technologies. Students' engagement with these areas demonstrates not only their technical proficiency but also a deep awareness of global issues such as climate change, resource management, and sustainability. The emphasis on practical applications of physics principles underscores the importance of integrating theoretical knowledge with real-world problem-solving. As Malaysia continues to focus on sustainable development and technological advancement, these student-led innovations offer valuable insights and potential solutions. Supporting such initiatives through education and policy can further enhance the impact of these innovations, driving progress towards a greener and more efficient future. Overall, the findings of this study suggest that innovation-oriented competitions can serve as powerful platforms for nurturing applied physics understanding among young learners. The diversity and relevance of the projects analyzed indicate that students are capable of moving beyond theoretical comprehension to meaningful application of scientific principles. By engaging in authentic problem-solving tasks, students develop critical

thinking, creativity, and design skills that are essential for future scientific and technological advancement. This reinforces the need for educational approaches that emphasize inquiry-based learning, experimentation, and interdisciplinary integration experiential and innovation-driven initiatives can play a crucial role in preparing the next generation for Malaysia's evolving economic and environmental landscape. The trends identified in this study not only reflect current national priorities but also demonstrate the potential of primary school students to contribute innovative ideas toward sustainable development. Continued support from educators, policymakers, and industry stakeholders will be essential to sustain this momentum and to ensure that physics remains a dynamic and transformative force in shaping Malaysia's innovation ecosystem.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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