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The Prospects and Challenges of STEM-PjBL with Design Thinking Strategies in Enhancing Students' Creativity and Entrepreneurial Thinking in the Context of Plastic Waste Recycling: Teachers' Perspectives

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Abstract: This STEM education a new trend of learning innovation. However, there are still many students who have not received integrated STEM education that focuses on developing 21st century skills. So that efforts to create learning innovations with a STEM approach become a challenge for teachers at every level of education, including in elementary schools. This study aims to explore teachers' views and challenges of integrated STEM learning Projecj-Based Learning (PjBL) with Design Thinking strategy and its potential in stimulating creative thinking and entrepreneurship. This study used the Cross-Sectional Survey methodology Explanatory Mixed Method design that has involved 250 elementary school teachers in Lampung Province. The results showed that most elementary school teachers do not have sufficient knowledge on how to develop STEM-PjBL learning innovation scenarios, especially in integrating Design thinking strategies in an effort to stimulate students' creative thinking and entrepreneurial skills. However, they believe that STEM-PjBL integrated with Design Thinking will provide learning experiences that stimulate students to think (minds-on) and be actively involved in project completion (hands-on). In addition, they also think that STEM-PjBL has the potential to prepare students to have a number of creative spaces and habituation in the classroom, especially in recycling plastic waste.

Keywords: Creative thinking; Design thinking; Entrepreneurial thinking; Learning module; STEM-PjBL

Introduction

Science and technology in the 21st century requires human resources that are dynamic and adaptive to every technological development and change (Indarta et al., 2022). The Ministry of Education and Culture of the Republic of Indonesia issued a new curriculum policy, namely the Merdeka Curriculum One of these adaptations is the shift from curriculum 13 to the independent curriculum which aims to realize an innovative and student-centered learning process (student-centered) Education and Culture of the Republic of Indonesia issued a new curriculum policy, namely the Merdeka Curriculum One of these adaptations is the shift from curriculum 13 to the independent curriculum which aims to realize an innovative and student-centered learning process (student-centered) Era Society 5.0 takes place in the 21st Century where learning already uses technology, the 21st century learning model also requires students to

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achieve 4C skills, namely critical thinking, communication, collaboration, and creativity (Indarta et al., 2021).

The independent curriculum is a curriculum that is able to develop the character of students through the development of the Pancasila student profile. The school has implemented the Pancasila student profile and is strengthening the Pancasila student profile where the development of the Pancasila student profile conducts project-based learning activities. The hope is that in the future students will become a society that has character values that are in accordance with the character values embedded in each point of the precepts of Pancasila (Safitri et al., 2022). Students who have creative thinking skills will be more adaptable, able to recognize various possibilities, able to overcome difficulties in a rapidly changing world, and able to process information from various points of view, one of the themes in P5 (Pancasila Student Profile Strengthening Project) is the theme of entrepreneurship (Ayub et al., 2023).

The principle of entrepreneurship is one of the skills applied from an early age to elementary school students in order to have a high quality of creativity and willingness to innovate from an early age (Rii et al., 2020). Educators must adjust the Education curriculum on the theme of entrepreneurship to equip students who are skilled in entrepreneurship (Bauman & Lucy, 2021). Provide opportunities for students to learn contextually by focusing on relevant issues, such as plastic waste management. Plastic waste is an environmental challenge that has not been properly addressed (Hachem et al., 2024). Indonesia, in particular, does not have an advanced waste management system with a growing population and consumption of plastic waste or plastic waste (Van Leeuwen & Surya, 2024). One of the main themes in P5 is entrepreneurship, where students are expected to develop basic entrepreneurial skills and creative learning experiences (Hidayat et al., 2021). The concept of entrepreneurship must be mastered or known by teachers and prospective teachers into educational programs and educational literature that are expected to educate future generations (Meral & Altun Yalçin, 2022).

Entrepreneurship education aims to develop entrepreneurial behavior and an independent attitude, not dependent on others can see things creatively so that they can always see opportunities from a problem that occurs (Nugraha et al., 2022). Entrepreneurship refers to the skills, character, attitude, and spirit of a person who has the traits and attitudes of an entrepreneur in himself, is able to manage emotions, skills, talents, will, and readiness to face all risks (Ratu et al., 2024).

The positive impact of entrepreneurship programs for inclusion in the primary school curriculum. Early introduction of entrepreneurship education in primary schools is essential to nurture the entrepreneurial spirit (Jardim et al., 2023). Entrepreneurship must have a creative and innovative spirit, Design Thinking is one of the strategies used to be able to see what opportunities consumers need (Dell'Era et al., 2020). Design thinking is an approach that the team will use to improve problem solving, trust and generate thoughts or ideas for entrepreneurial activities, design thinking encourages the development of creative skills that allow one to look at problems from different angles (Chanal & Merminod, 2020). Design thinking is one of the tactics used, and uses appropriate teaching methodologies. Students' 21st century higher order thinking skills can be stimulated by STEM methods (Ning et al., 2023). The development of technology 4.0 and social 5.0 has a big influence, students must have the competencies needed for the development of the times, one of the models that can be used in 21st century education is STEM-PjBL which is considered successful in improving student abilities through project-based learning techniques, this learning paradigm can combine interdisciplinary knowledge of science, technology, engineering, and mathematics (Nurhasnah et al., 2023).

Project based learning (PjBL) can facilitate contextualized learning through exercises focused on students' final outcomes after a series of projects (Guo et al., 2020). PjBL learning requires students to actively participate in entrepreneurial learning activities that demand creative thinking skills in producing a product (Namruddin et al., 2024). The design thinking strategy combined with the STEM-PjBL approach is considered to help students understand topics more fully, complete projects given by teachers, develop an entrepreneurial spirit in elementary schools. Educators should develop educational programs, stimulate students to think creatively to develop data skills, intuition, which will help them to continue to succeed (Donoghue et al., 2021).

PjBL STEM learning with design thinking strategy is usually applied in high school, junior high school (Rabbani et al., 2023). Design thinking is used in universities (Huyen, 2024). The elementary school level has not yet implemented STEM PjBL learning with design thinking strategies that distinguish this research from previous research is using PjBL STEM learning with design thinking strategies. The environmental theme is the focus of researchers with waste recycling material to overcome environmental pollution due to soaring plastic consumption (Dokl et al., 2024). Recycling aims to tackle plastic waste and reuse innovative and creative products and keep the environment clean (Perera et al., 2025). By integrating plastic waste into new products and materials, recycling supports a sustainable and environmentally friendly

economic model (Sipra et al., 2024). Plastic waste management has become a significant environmental and social problem worldwide (Abdullah & Abedin, 2024). Inorganic waste takes a very long time to decompose, it is important for policy makers to encourage collaboration for effective plastic waste management to tackle environmental pollution due to plastic waste (Pongpunpurt et al., 2024).

With the rapid increase in the number of plastic products, recycling plastic waste has become an important challenge around the world (Hao et al., 2024). Plastic use is increasing as a result of lifestyle changes, cost-based incentives, and other factors (Ganguly & Chakraborty, 2024). The waste problem cannot be solved by one party alone, but requires synergy from all groups, including the elements of educational institutions. The role of educational institutions such as schools is vital in providing education and understanding to students and teachers about proper waste management (Suriani et al., 2022).

Daily activities in schools that generate waste should be resolved by the school itself, but with environmentally sound rules. Independent steps in managing waste can certainly reduce the amount of waste and have a positive impact on the environment. Efforts to deal with waste can realize that the environment is maintained and sustainable (Bahtiar, 2022). Schools play an important role in shaping the habits of students and teachers to care about the environment through wise waste management (Eka Budiarti et al., 2023), especially plastic waste with STEM-PjBL learning with design thinking strategy on the theme of entrepreneurship to recycle plastic waste with economic value.

Preliminary research findings based on a survey of 250 elementary school teachers in Lampung province revealed that there has not been much STEM-PjBL using design thinking strategies, especially to increase student creativity and entrepreneurship in recycling plastic waste. Nonetheless, the curriculum, learning infrastructure and facilities are appropriate to make students think creatively and entrepreneurially. The majority of teaching in schools uses textbooks (Harsiwi & Arini, 2020). Teachers still use conventional techniques to deliver learning due to less effective learning resources (Winangsih & Harahap, 2023).

Method

This study used a mixed-method (Creswell & Poth, 2018) A cross-sectional with an explanatory mixed methods design was used in this investigation. The research approach, known as mixed research, combines quantitative and qualitative components. The study was conducted in Lampung, Indonesia, in primary schools. A total of 250 elementary school teachers participated in this study. Google Forms was used to create a questionnaire that was distributed online Google Forms was used to create a question that was distributed online to collect information on teachers' opinions regarding STEM-PjBL integrated learning and the instructional resources used in the process. There were three components that made up the questionnaire: design thinking techniques, STEM-PjBL integrated teaching materials, and entrepreneurial aspects of plastic waste recycling and creative thinking. In the early stages of the study, the teacher needs questionnaire was used as a tool to collect data on the instructional strategies used and the findings from examining the instructional programs used by teachers.

There are three components that make up the questionnaire: design thinking techniques, STEM-PjBL integrated teaching resources, and creative thinking skills. In addition, a percentage-based description and qualitative interpretation of the results of the questionnaire analysis regarding the needs of teachers and students are provided. The survey used a Guttman scale, with answer options corresponding to the content of the questions: "Yes" and 'No', with a score of '1' or '0' (Bong & Firmansyah, 2023). The percentage of respondents for each item in the questionnaire and the interpretation of the answers in the form of descriptive narratives classified as excellent, good, very good, and less good were used to analyze the data. Using the percentage of answers for each item asked, the questionnaire data was examined. Both studies have the same priority as triangulation and integration. The research design scheme can be seen in the following figure:

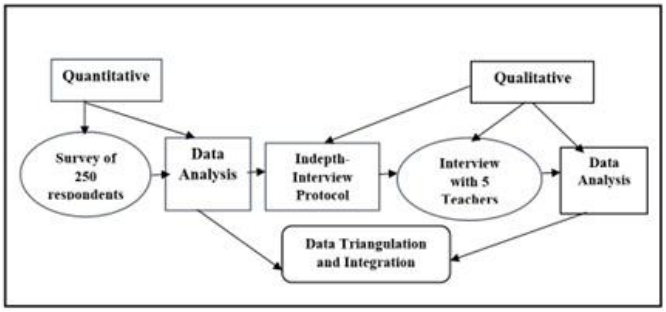

Figure 1. Cross-sectional mixed-method research design

The sequential research stages are shown schematically in Figure 1, with the qualitative research conducted first and the quantitative research conducted afterward, both of which are in line with the sequential stages of explanatory design. The first step was to collect and analyze qualitative data based on the findings from the initial exploratory investigation. The next step is to

use a quantitative approach (survey of 250 respondents) to evaluate or generalize the initial findings and analyze how the initial findings (interviews with 5 teachers) were used to build on the qualitative research results. Create an instrument based on the first stage findings to determine the overall prevalence over a longer period of time.

Result and Discussion

The results of teacher perceptions of the Entrepreneurship Theme Learning Program on Plastic Waste Recycling Integrated STEM-PjBL with Design Thinking Strategy to Stimulate Creative Thinking and Entrepreneurship are shown in Table 1.

The findings show that only 33% of teachers are familiar with STEM, which means that up to 67% of teachers are unaware of it. This makes it difficult to implement STEM education, which aims to improve students' science, technology, engineering and math skills. Few teachers use STEM-oriented learning in elementary schools; most STEM research is used in middle and high schools. In addition to the project-based learning paradigm, modern education must integrate STEM, a learning strategy that focuses on teaching students across four disciplines, to remain relevant in the era of globalization. Students' knowledge can be deepened through STEM education by making their learning more meaningful and relevant (Abdurrahman et al., 2023).

Table 1. Interpretation Results of Teacher Perception Questionnaire

Question	Percentage (%)	
	Yes	Yes
Have you ever heard of STEM?	33	67
Have you ever studied STEM-PjBL based learning?	37.2	62.8
Have you ever applied STEM-PjBL based learning to entrepreneurship learning on waste recycling material?	20	80
Does the learning relate the material taught to daily life, for example, hygiene?	46	54
Have you ever heard of design thinking?	40	60
Have you ever learned about design thinking?	30	70
Have you ever applied design thinking to entrepreneurship learning on waste recycling?	24	76
Does the entrepreneurship theme of plastic waste recycling material use design thinking strategies?	70	30
Have you ever assessed students' skills in entrepreneurship learning according to the indicators of creative thinking?	20	80
Have you ever designed a lesson to train entrepreneurial skills for recycling plastic waste?	10	90
Does the classroom learning always involve students in finding a problem?	45	55
Does the learning provide opportunities for learners to learn to propose ideas from problems in the environment?	60	40
Are learners guided in their learning to come up with ideas that are supported by data?	35	65
Do you guide learners in revising ideas through discussion?	70	30
Does the learning strategy chosen in the classroom train students to solve social problems related to science or technology?	32	68
Are the teaching materials used in learning in accordance with the phenomena, problems, social scientific issues that students encounter in everyday life?	69	31
Are the learner worksheets that you use appropriate to train the skills needed by learners in solving problems in everyday life?	65	35
Is there a need for a STEM-PjBL based entrepreneurship theme learning program with design thinking strategies to stimulate creative thinking and entrepreneurship on plastic waste recycling material for students?	92.4	7.6

The role of STEM (science, technology, engineering and math) in developing 21st century competencies. STEM is a strategy that uses a tangible framework to incorporate science, technology, engineering and math into learning activities (Hariyadi et al., 2023; Ichsan et al., 2023; Ilafi et al., 2024; Nazifah & Asrizal, 2022; Sujud et al., 2024; Zulyusri et al., 2023). Developing students' creative thinking skills in entrepreneurship education, indications of entrepreneurial success and creative thinking are examined. The process of using high-quality resources to create a product, either by creating a new product or changing an existing product, is called creativity in recycling plastic waste. Because plastic recycling is a worldwide problem due to the damage that plastic causes as a whole, both to the environment and human health (Bharadwaaj et al., 2024).

To generate innovative ideas and facilitate business success, educators must adopt a creative mindset that encourages teachers to adapt their teaching methods to the current context, rather than relying solely on tried-and-tested techniques. The findings of this study corroborate this: up to 62.8% of educators had never heard of STEM-PjBL integrated learning, while 37.8% had. In addition, 80% of educators have never used STEM-PjBL integrated learning to teach entrepreneurship, and 54% of educators who have

taught have not connected the subject matter to real-world experiences (Aini et al., 2024). One of the benefits of using a STEM approach is developing students' ability to use design knowledge to solve problems (Dewanto et al., 2024; Dewi et al., 2023; Nurhaisa et al., 2023; Setiawati et al., 2024; Subari & Mercuriani, 2024).

Only 46% of educators relate the content they teach in class to real-world situations. In addition, 40% of educators said they had heard of design thinking, compared to 60% who said they had not. In addition, only 30% of teachers have heard of design thinking, and 70% of teachers have never done it. 24% of teachers have used design thinking in their entrepreneurship teaching, compared to 76% who have not. 30% of teachers said that design thinking lessons are included in the entrepreneurship sub-matter, while 70% of teachers said that the entrepreneurship sub-matter includes such lessons. This shows that while design thinking techniques are commonly used in universities as a result of academic research, they are not yet commonly applied in primary schools. This shows that design thinking techniques have not been commonly applied in schools (Kremel & Wetter Edman, 2019).

Up to 80% of teachers have never evaluated students' entrepreneurial learning ability in creative thinking, and only 20% have done so. 20% of teachers have not created lessons to foster entrepreneurial skills, while the other 80% have done so. Of the teachers surveyed, 45% said that classroom learning has always engaged students in problem solving, and 55% said that classroom learning has not done its best to engage students in problem solving. A total of 40% of educators have not given their students the opportunity to practice making suggestions. As higher order thinking skills have now been integrated into education at every level and subject in Indonesia (Rahmawati, 2022). As much as 60% of learning provides learners with opportunities to learn how to propose ideas.

Table 2. Summary of Teacher Interview Results

Interview Protocol	Teacher Response
What instructional strategies do you employ to ensure that each student fully understands and follows the lesson?	The method used is generally expository, where the teacher explains, students use teaching materials in the form of books available at school to complete exercises/tasks.
Is it a method that works? How much impact does it have in facilitating effective learning and addressing environmental concerns?	In some topics, the method is quite effective and quite impactful for students, although it has not made students actively participate in learning but has not been enough to overcome the plastic waste problem.
When you teach in a classroom, how do the students react?	Learners' responses sometimes look bored and sometimes enthusiastic
When you teach, how do you prepare the students?	Condition the class with ice breaking or making games
When you teach, how is the classroom set up?	The condition of the class during teaching is quite conducive, there are some children who pay attention and some children who do not pay attention.
How suitable is the average student to learn about the entrepreneurship of plastic waste recycling?	Students are a little confused because they don't really understand what they want to make in entrepreneurship.
What techniques do you use to learn entrepreneurship? Are the students engaged with the methods? To what extent does learning media play a role in the teaching and learning process?	Using the discovery learning model, question and answer method, discussion and resitation
Do you personally know of any students who struggle in entrepreneurship classes? What are the reasons behind this?	Very knowledgeable, because students do not understand the meaning of entrepreneurship and what indicators determine the success of entrepreneurship.
How can you overcome students' barriers when they try to learn entrepreneurship?	Using teaching materials downloaded from the internet
What techniques do you use to learn entrepreneurship? Are the students engaged with the methods? To what extent does learning media play a role in the teaching and learning process?	Lecture and question and answer method
How can you overcome students' barriers when they try to learn entrepreneurship?	By explaining directly and helping the difficulties experienced by students
In terms of entrepreneurship lessons, what potential do you believe students can develop?	Think creatively and take leadership and decide on the target and the product you want to make
Do you make connections between the subjects taught in class and everyday life? If yes, give an example	Sometimes linking and sometimes not yet linking
Do you assist students in addressing social issues in the context of science and technology within the framework of STEM education? What is the extent of student engagement in the conversation?	In the classroom, it is enough to guide and discuss the problems faced and the response of students is quite good because students express what problems they face.

Interview Protocol	Teacher Response
Have you tried combining the design thinking approach with STEM-PjBL-based plastic waste recycling material entrepreneurship education? If yes, what kind of material?	Never implemented and do not understand how to design STEM-PjBL learning module with design thinking strategy.

65% of teachers said that students were not guided to present ideas supported by data during the learning process, while 35% of teachers said that students were guided to present ideas supported by data during the learning process. According to 70% of teachers' responses, 30% of the learning that takes place in the classroom does not involve guiding students to modify ideas through conversation. In addition, according to 68% of teachers, the learning approach chosen has not been preparing students to address social issues related to science or technology in the classroom and 32% of classroom teaching, the chosen learning approach has equipped students with the necessary skills to address science or technology-based social issues. The STEM approach applies science, technology, engineering and math in a context that connects the classroom, community, workplace and global enterprise. The curriculum combines challenging academic principles with practical lessons. Improving life skills, advancing careers and boosting the global economy are just some of the ways that STEM enhances educational interventions in learning and places them in the context of everyday life. For example, improving academic performance and developing 21st century skills (Puspitarini, 2022).

A total of 69% of teachers reported that when learning takes place in the classroom, the materials used are appropriate to the problems, phenomena, and social scientific issues faced by students on a daily basis, while 31% of teachers reported that when learning takes place in the classroom, the materials used are not appropriate to the problems, phenomena, and social scientific issues faced by students on a daily basis. In addition, 65% of teachers responded that the student worksheets used in class were appropriate for teaching the skills students need to solve problems in everyday life, and 35% said that the student worksheets used in class were not appropriate for teaching the skills students need to solve problems in everyday life. Furthermore, 92.7% of educators responded that to foster students' innovative and entrepreneurial thinking, a STEM-PjBL Integrated Entrepreneurship Theme Learning Program with Design Thinking Strategy is needed to foster creativity in business to address environmental issues, namely recycling plastic waste, a teacher can help students develop their thinking ability and get ready for a better learning experience.

Furthermore, specific questions about teachers perceptions of the potential and success of STEM-PjBL learning with Design Thinking Strategy were collected and transcribed below:

The first teacher (Sub-Urban) said that: "the use of STEM and Design Thinking in PjBL is likely to help stimulate students' creative thinking skills". In addition, the teacher also stated: "in STEM-PjBL there is potential in creating innovative solutions and developing new ideas, for example addressing the problem of plastic waste and providing a strong foundation for future entrepreneurial skills."

The second teacher (Rural) emphasized that: "the integration of Design Thinking in STEM PjBL has the potential to help learners understand the concepts of creativity and innovation in a real-world context. It is also predicted to motivate learners to explore their entrepreneurial potential, open the door for the development of original and sustainable business ideas and overcome the problem of plastic waste that is only burned and produces smoke that is not good for breathing and difficult to decompose."

The third teacher (Urban) revealed that: "Design thinking strategies in STEM-PjBL learning have the potential to stimulate creative thinking skills and entrepreneurship by teaching students to see opportunities from environmental problems, for example plastic waste and provide solutions to each problem, for example recycling plastic waste into goods that can be resold.

The design of this learning model is likely to assist students in improving their ability to identify business opportunities and formulate solutions that are not only effective but also innovative."

Based on the explanation above, it is believed that the use of STEM-PjBL-based learning programs with Design Thinking strategies on entrepreneurship in plastic waste recycling material is close to the context of daily life. The following is the design of STEM integration in the learning program based on the results of observations and interviews (Hypothetical Design).

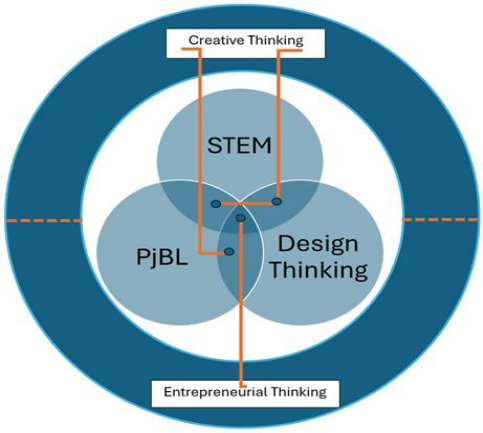

Figure 2. Design of STEM-PjBL integration and design thinking for entrepreneurial thinking (Hypothetical Design)

Creating modules is one approach to putting learning theories and programs into practice. Learning in the form of modules is a curriculum-based and time-based learning program that is structured to make learning more efficient, applicable, and able to provide new knowledge and skills to teachers and students. When it comes to helping students learn mathematics in the 21st century, learning modules play an important role. In addition to providing independent learning tools for students (Ichsan et al., 2023).

As a result, encouraging students to take an active role in the learning process helps foster their entrepreneurship and innovative thinking. Through the integration of STEM-PjBL teaching materials with design thinking strategies, students can culminate in the systematic compilation of experimental processes for the production of entrepreneurial products. To encourage students' creativity and entrepreneurial spirit, they can explain the product idea they want to create and sell. By examining the cost of materials needed to make the product and its selling price, students can gain more information in various subjects. Careful program preparation is necessary to enhance the entrepreneurial spirit in primary schools. This is because program planning serves as a roadmap for implementing activities, so everything needs to be planned to deliver results consistent with the objectives and reduce environmental pollution from plastic waste. As a result, the curriculum facilitates learners' understanding of entrepreneurship-related learning resources with environmental peers and a focus on student-generated plastic waste. Teachers create educational resources to encourage students' innovative and entrepreneurial thinking. To learn in the classroom, students must focus on their teachers. Science-based project modules, along with an integrated STEM-PjBL approach and Design Thinking techniques, greatly enhance conceptual learning, to provide students with opportunities to learn Science, Math, and Engineering through the process of addressing real-world problems. STEM (science, technology, engineering, and math) is an interdisciplinary learning approach that teaches academic topics alongside real-world applications of these subjects.

Conclusion

Based on survey and indepth-interview results, educators generally support the STEM-PjBL-based entrepreneurship theme learning program that incorporates design thinking techniques to foster students' entrepreneurial spirit and innovative thinking. The majority of teachers have not used the STEM-PjBL approach, based on a review of its implementation in the classroom. In order for STEM-PjBL learning using Design Thinking techniques to enable independent curriculum learning, this approach teaches students not only in science exploration but also in math skills and conceptual understanding. To engage students in the learning process, entrepreneurship education that integrates STEM-PjBL method with Design Thinking strategy has the ability to produce learning that is focused on giving them the tools they need to think creatively and entrepreneurially and make the environment beautiful and clean.

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Author Contributions
D. U.: conceptualized and selected the methodology, prepared to write the original draft, carried out analysis according to the methodology, conducted research, and wrote down the results and discussed the research results. A., D.L., and N. H.: as supervisors and research data validators.

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Conflicts of Interest
The authors declare no conflict of interest.

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