ASEAN Journal of Educational Research and Technology

Journal homepage: https://ejournal.bumipublikasinusantara.id/index.php/ajert

Enhancing Innovative Thinking through a Theory-Based Instructional Model in Design Education to Support Sustainable Development Goals (SDGs)

Rui Di, Tatsirin Sawangboon[*]*, Jiraporn Chano*

Mahasarakham University, Mahasarakham, Thailand
Correspondence: E-mail: tatsirin.s@msu.ac.th

ABSTRACT

This study aimed to develop an instructional model that enhances innovative thinking skills in interior design students by integrating emotional design theory, constructivist learning theory, and creative thinking theory. Using a research and development approach, the model was constructed through needs analysis, expert validation, and empirical implementation. Pre-test and post-test comparisons, along with classroom observations and student feedback, demonstrated significant improvement in flexibility, fluency, originality, and precision of thinking. The model was particularly effective because it aligns theoretical learning with practical application, encouraging student engagement and deeper cognitive processing. As a result, students demonstrated increased creativity, improved design output, and greater collaborative capacity. The instructional model presents a promising framework for fostering innovation in design education. This study supports current issues in Sustainable Development Goals (SDGs).

ARTICLE INFO

Article History:
Submitted/Received 03 May 2025
First Revised 01 Jun 2025
Accepted 07 Aug 2025
First Available online 08 Aug 2025
Publication Date 01 Dec 2025

Keyword:
Contructivism,
Design education,
Emotional design,
Instructional model,
Innovative thinking.

1. INTRODUCTION

The rapid development of science and technology has marked the beginning of the "Internet+" era and continues to progress toward an age driven by artificial intelligence (Fadillah *et al*., 2022; Adebayo & Ochayi, 2022; Anjum & Bhatti, 2024). In this new context, repetitive mechanical tasks are increasingly delegated to machines, while human labor is shifting toward creative and intellectual functions. Consequently, global competition has evolved into a contest of national innovation capacity, positioning education at the core of talent cultivation. Educational institutions are now responsible for fostering individuals with both innovative mindsets and practical skills to drive societal advancement.

Innovative thinking plays a pivotal role in national development and individual progress. It has become a central concern in academic discourse, especially within the context of higher education (Glushchenko, 2023). Universities and colleges are expected to produce graduates who are not only technically competent but also capable of original thought and creative problem-solving (Xu Dongmei, 2018; Guo & Deng, 2020; Prasojo *et al*., 2025). However, many existing instructional models in design education tend to equate basic design learning with mere technical training, often focusing on tools and techniques while neglecting conceptual exploration and holistic design understanding (Liu et al., 2020).

Several challenges persist in fostering innovative thinking through conventional instructional approaches. First, the role of the teacher remains largely didactic, which limits students' opportunities to explore and experiment creatively. Second, while modern pedagogical strategies such as project-based learning have shown potential to nurture innovative thinking, their application is restricted due to institutional inertia and limited technological infrastructure. Third, the dominance of standardized testing in educational assessment sidelines the measurement of critical and creative thinking, causing students to prioritize grades over intellectual growth (Zang, 2018).

Interior design, as an interdisciplinary and practice-oriented field, particularly requires students to develop strong innovative thinking skills. These skills enable them to understand user needs, solve spatial problems, and create meaningful, emotionally resonant environments. Addressing these educational gaps, this study aims to develop and evaluate the DIIEE instructional model (comprising Discovery, Interpretation, Ideation, Experiment, and Evaluation) to enhance innovative thinking among interior design students. Grounded in emotional design theory and constructivist learning principles, the model is intended to foster a student-centered, iterative learning process that integrates user empathy and creative problem-solving in the context of design education. The novelty of this study lies in its integration of emotional design theory, constructivist learning theory, and innovative thinking theory into a unified instructional model specifically tailored for the interior design discipline. This model not only bridges theory and practice but also incorporates a structured evaluation system for measuring students' growth in fluency, flexibility, originality, and precision. Through empirical validation, the model offers a replicable framework for improving innovation-oriented pedagogy in design education. This study supports current issues in Sustainable Development Goals (SDGs).

2. LITERATURE REVIEW

At the heart of interior design education lies the cultivation of innovation, a process not merely technical but deeply emotional and reflective. Emotional design theory, as proposed by Norman, emphasizes the significance of affective engagement in shaping user-centered solutions that are both functional and meaningful (Fokkinga *et al*., 2020). **Figure 1** illustrates

the theoretical foundation connecting emotional design, constructivist learning, and innovative thinking, which supports the DIIEE instructional model adopted in this study. Emotional engagement influences not only students' ideation processes but also their motivation to persist through complex design challenges (Wang, 2022).

In tandem with **Figure 1**, **Table 1** presents the Emotional Design-Oriented Instructional Strategy Framework, which operationalizes this theoretical alignment into pedagogical practice. The table outlines five instructional phases: Discovery, Interpretation, Ideation, Experiment, and Evaluation, each tied to emotional foci, learning activities, and expected student responses. This structure draws upon constructivist learning theories that emphasize student agency, contextual learning, and reflective practice (Juvova *et al*., 2015). In the Discovery phase, students encounter real-world problems that evoke curiosity and critical questioning. The Interpretation phase engages empathy by encouraging learners to understand user experiences and emotional needs. Ideation fosters creativity through brainstorming activities aimed at joyful and inspired problem-solving. The experiment phase supports resilience as students prototype and iterate, while Evaluation promotes reflective learning through self-assessment and peer critique (Rickey *et al*., 2023; Mirattanaphrai & Srikoon, 2025). Together, these phases align emotional experiences with pedagogical intentions, nurturing both cognitive and affective dimensions of innovative thinking.

Moreover, this model connects with prior research on design-based education, which underlines the importance of iterative cycles, problem framing, and user-centered evaluation (Hernández-Leo *et al*., 2018). Unlike conventional design instruction that often prioritizes aesthetic and technical outcomes, the emotional design approach fosters deeper learner engagement by making emotion an explicit part of the learning process. It also aligns with 21st-century skills, emphasizing empathy, adaptability, and creative risk-taking (Nasser, 2024). Studies show that when students feel emotionally connected to their work, they are more likely to persist through complexity and uncertainty, traits essential for innovation (Fredrickson, 2001). Hence, a model such as DIIEE may serve not only as a pedagogical framework but also as a transformative tool for creative education.

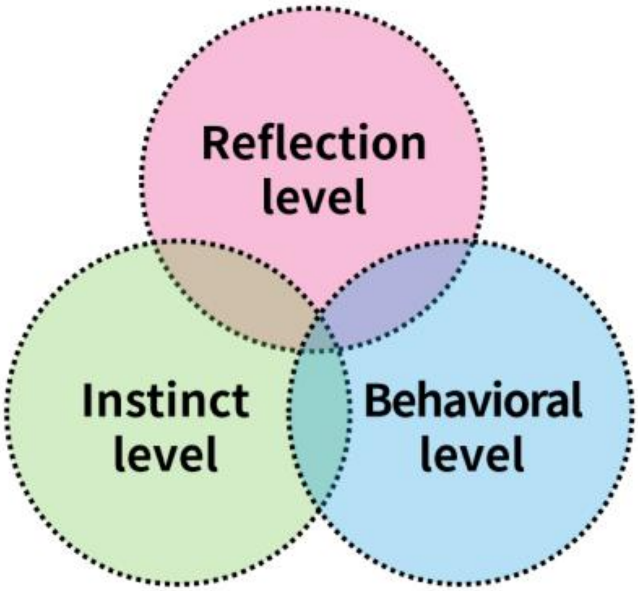

Figure 1. Theoretical framework of emotional design and innovative thinking in the diiee model.

Table 1. Emotional design-oriented instructional strategy framework.

Instructional Phase	Emotional Focus	Learning Activity	Expected Student Response
Discovery	Curiosity, Intrigue	Present real-world design problems	Active exploration and questioning
Interpretation	Empathy, Perspective-taking	Analyze user needs and emotional experiences	Emotional engagement with user context
Ideation	Inspiration, Enjoyment	Brainstorm multiple creative solutions	Generation of diverse, novel ideas
Experiment	Risk-taking, Resilience	Prototype and test selected design solutions	Willingness to fail and learn from feedback
Evaluation	Satisfaction, Reflection	Critically assess design outcomes and process	Reflective insight and metacognitive growth

3. METHODS

This study employed a Research and Development (R&D) design, specifically adapted from the ADDIE model, which includes Analysis, Design, Development, Implementation, and Evaluation. The objective was to create and validate an instructional model that enhances students' innovative thinking in the field of interior design. The research process was structured into three main phases: (i) theoretical model development, (ii) instructional model construction, and (iii) model implementation and validation. To begin, a needs analysis was conducted through interviews and document reviews to understand the current limitations in cultivating innovative thinking among design students. These data informed the theoretical basis for the instructional model, which integrated emotional design theory, constructivist learning principles, and innovative thinking components such as fluency, flexibility, originality, and precision.

Table 2 provides an overview of the research participants involved in the implementation phase. The participants in the implementation phase consisted of 89 second-year undergraduate students majoring in interior design at a vocational college. The sample was selected using stratified purposive sampling to ensure diversity in academic performance and design skill level. Instruction was delivered during the Fundamentals of Creative Design course, which served as the platform for testing the instructional model's effectiveness.

Table 2. Overview of the research participants.

Category	Description
Total Participants	38 undergraduate interior design students
Gender Distribution	19 female (50%), 19 male (50%)
Age Range	Until 23 years (under 18 years (5%) and 18-23 years (95%)
Academic Year	Second-year and third-year students
Selection Criteria	Enrolled in a design studio course using the DIIEE model
Location	A major university design program in China

The instructional design included both classroom-based and project-based learning activities. The instructional model was developed in alignment with the theoretical framework, emphasizing the DIIEE process: Discovery, Interpretation, Ideation, Experiment, and Evaluation. Each stage was paired with targeted instructional strategies such as

brainstorming, association techniques, morphological analysis, and the KJ method. Emotional engagement was fostered through activities that encouraged students to reflect on user needs and integrate empathy into their creative solutions (Yu & Nagai, 2020).

To evaluate students' development in innovative thinking, a combination of quantitative and qualitative methods was applied. The Williams Creative Thinking Test was administered as both a pre-test and post-test to measure changes in fluency, flexibility, originality, and precision (Rababah, 2018). Classroom observation, teacher reflections, student interviews, and peer evaluations were also conducted to triangulate findings and understand the experiential impact of the instructional model. All data were analyzed using descriptive statistics and content analysis techniques to assess the model's validity and effectiveness (Zang, 2018).

Ethical considerations were addressed through informed consent and the anonymity of participants. The study was conducted following academic research guidelines and approved by the institutional research ethics board.

4. RESULTS AND DISCUSSION

Figure 2 provides a comprehensive visual representation of the key components and process of the innovative thinking instructional model developed in this study. The instructional model developed through this study consists of five stages (Discovery, Interpretation, Ideation, Experiment, and Evaluation (DIIEE)) supported by theoretical foundations drawn from innovative thinking theory, emotional design theory, and constructivist learning theory. The figure also demonstrates how these stages interact dynamically, with feedback loops enabling reflective improvement throughout the learning process.

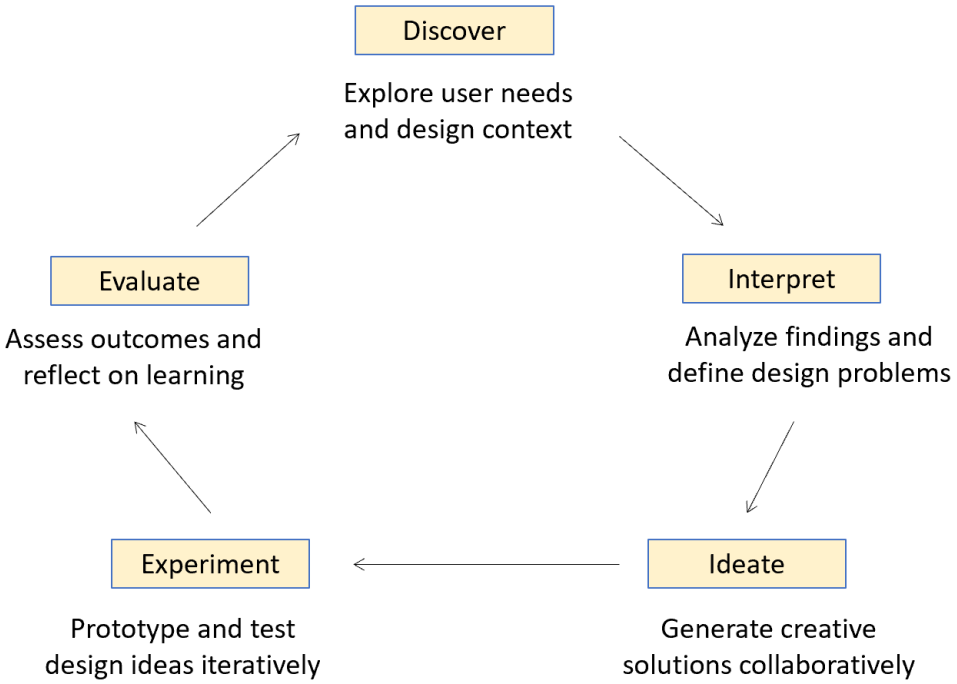

Figure 2. The innovative thinking instructional model for interior design education.

In the implementation phase, this model was applied in a real classroom environment involving 89 students in a Fundamentals of Creative Design course. The model was embedded

into the learning process through project-based and emotion-driven design tasks. Pre- and post-assessments were conducted to evaluate the development of students' innovative thinking across four key indicators: fluency, flexibility, originality, and precision, as measured by the Williams Creative Thinking Test.

The first stage, Discovery, involved activities that encouraged students to explore user needs, identify real-world problems, and gather relevant contextual information. During this phase, students worked in groups to conduct design investigations using techniques such as mind-mapping, interviews, and environmental scans. They also practiced empathy mapping to better understand the users' emotional and functional needs.

Qualitative observations showed that many students initially struggled with open-ended problem formulation. They were accustomed to receiving pre-structured assignments and displayed hesitation when asked to define problems on their own. However, with instructor guidance and collaborative peer discussions, most groups were able to articulate insightful problem statements. This finding confirms earlier studies emphasizing the role of scaffolding in constructivist environments to guide students from dependence to independence (Chin & Osborne, 2010).

In the Interpretation stage, students synthesized the data collected in the discovery phase and translated it into design criteria. This involved categorizing needs, formulating user personas, and creating conceptual maps. The KJ method, a tool for organizing qualitative data, was particularly useful in helping students distill large volumes of information into manageable insights.

At this stage, cognitive flexibility began to emerge as students demonstrated the ability to view the problem from multiple perspectives. Peer feedback sessions were critical in this phase, as they exposed students to alternate interpretations and encouraged constructive debate. This aligns with the findings that structured peer interaction enhances flexibility by forcing students to consider alternative ideas they may not have generated on their own (Zang, 2018).

The third stage, Ideation, focused on generating creative solutions. Brainstorming and association techniques were employed to encourage divergent thinking. Each group was tasked with producing a minimum of ten concept sketches based on the refined problem statement. The ideation phase was supported by emotional design principles, prompting students to consider how their solutions could evoke positive emotional responses from users. Activities such as storytelling and persona immersion helped students connect emotionally with their concepts, making their design choices more human-centered.

It was during this phase that students' originality became most evident. Several groups generated ideas that combined functionality with symbolic or narrative elements, for instance, a study corner that adapts to mood lighting based on emotional states, or a modular workspace inspired by origami folding principles. This result is consistent with the notion that original ideas often emerge from associative and analogical thinking processes, especially when emotional engagement is high (Yu & Nagai, 2020).

Post-test scores for originality showed a marked improvement compared to the pre-test, indicating that the structured ideation strategies were effective in nurturing this skill. These results mirror those of previous study (Aldig & Arseven, 2017), who found that creative tools embedded in the learning process significantly enhance students' originality and confidence in expressing novel ideas.

In the Experiment stage, students built mock-ups, physical prototypes, or 3D digital models of their selected design concepts. This phase encouraged precision and iterative problem-

solving. Students conducted usability testing by inviting peers to interact with their models and provide feedback, which was then used to refine their work.

This hands-on process allowed students to experience the value of experimentation and iterative improvement. It also highlighted the importance of constraint-based thinking; students had to adjust their ideas in response to material limitations, user feedback, or spatial constraints. These findings align with research on the role of experiential learning in design education, which underscores that prototyping sharpens precision while reinforcing the connection between ideation and real-world applicability (Boucharenc, 2006).

Table 3 illustrates the comparative results of students' pre-test and post-test scores across the four indicators. **Table 3** presents a comparison of students' scores in fluency, flexibility, originality, and precision before and after implementation of the instructional model. Notably, all four indicators exhibited measurable improvement. Originality and flexibility showed the highest gains, suggesting that the ideation and interpretation phases of the model had the greatest impact. Meanwhile, precision improved more modestly, likely due to students' limited prior experience with prototyping tools.

Table 3. Comparison of students' innovative thinking scores before and after model implementation.

	Flexibility		Fluency		Originality		Precision	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Mean	13.13	16.95	13	18.26	11.63	18.53	10.55	17.71
Standard Deviation	2.34	2.34	2.49	1.87	2.36	2.17	2.66	2.31
t	-7.116		-10.41		-13.257		-12.525	
Sig. (two-sided)	0		0		0		0	

A deeper analysis of student reflections revealed recurring themes regarding the value of structured creativity. Many students expressed appreciation for the balance between guided strategies and personal freedom. They noted that the emotional design framework helped them "design with feeling," enabling them to connect with user needs on a deeper level.

Several students also commented on how the constructivist approach helped them develop metacognitive awareness. By reflecting on how they learned and made decisions, they became more conscious of their thinking processes, a critical component in the development of creative confidence (Dwyer *et al*., 2021). This echoes the argument (Xu, 2018) that constructivist environments support not only content mastery but also cognitive regulation.

In terms of group dynamics, observations revealed that collaboration was both a strength and a challenge. While most groups benefited from collective brainstorming and shared responsibilities, some experienced friction due to differing work styles or unequal contributions. This highlights the importance of embedding team-building activities and clear role assignments in project-based courses to maximize group productivity and learning equity.

To assess the practicality and sustainability of the model, the instructor conducted a reflection session at the end of the course. Based on qualitative feedback, the model was considered effective, but several areas for refinement were identified. For instance, students

requested more time for the experiment phase and suggested that prototyping tools be introduced earlier in the semester. These suggestions will inform the next iteration of the instructional design.

The findings of this study underscore the value of an integrated model that blends theoretical constructs with practical application. Unlike fragmented instructional approaches that target only one aspect of innovation, the DIIEE model engages cognitive, emotional, and behavioral dimensions in a cyclical and student-centered process. As such, the model contributes a novel framework to the discourse on interior design education and offers actionable insights for educators seeking to foster innovative capacity among students.

The effectiveness of the model was also confirmed through qualitative data collected via classroom observations and student interviews. During the observation phase, students became increasingly autonomous in their decision-making and demonstrated a higher level of engagement during discussions. Instructors reported that students asked more insightful questions and made reflective comments about their design choices, particularly concerning user needs and emotional impact. These behavioral changes suggest the development of both cognitive and affective engagement, which are considered essential for fostering deep learning.

One compelling example came from a student group designing a multi-functional reading corner for small urban apartments. Initially, their design merely replicated existing solutions found online. However, after engaging with the emotional design phase, they reframed their objective to create a “safe emotional cocoon” for users experiencing stress. The resulting design incorporated sensory elements like adjustable lighting, sound-absorbing panels, and textures chosen for emotional warmth. This shift illustrates how the integration of emotional engagement redefined their design process and outcome, leading to both novel and empathetic solutions.

This aligns with Norman’s theory of emotional design, which argues that products that engage users emotionally tend to be more effective, memorable, and successful. Students’ reflections revealed that by imagining the emotional experience of the user, they became more invested in the purpose behind their designs. Emotional connection, therefore, served as both a motivational driver and a design strategy, which reinforces the theoretical underpinnings of this instructional model.

Furthermore, feedback collected from peer evaluations provided additional evidence of students’ growing awareness of design innovation. Students were asked to assess each other's work based on innovation, feasibility, user-centeredness, and emotional impact. Many comments focused not just on visual appeal or function, but on how well the design responded to the user's emotional state, suggesting that the evaluation framework successfully cultivated a broader understanding of design quality.

Table 4 summarizes the qualitative findings derived from student feedback and instructor reflections during the implementation of the instructional model. Students frequently mentioned terms such as “empathy,” “freedom to explore,” “user feelings,” and “creative flow” in their reflections. Instructors, on the other hand, emphasized students' increased participation, improved collaboration, and heightened curiosity. This dual-source feedback confirms that the model impacted not only cognitive outcomes, as reflected in test scores, but also affective and behavioral dimensions of student learning.

Table 4. Thematic summary of student reflections and instructor observations.

Theme	Student Reflections	Instructor Observations
Emotional Engagement	"I felt excited when interpreting the user's needs—it felt like storytelling."	Students showed increased verbal expression and enthusiasm during empathy sessions.
Creative Confidence	"At first, I was unsure, but prototyping helped me trust my ideas more."	Students took more initiative and risks in idea generation.
Resilience	"When my first idea failed, I didn't feel bad. I just tried something else."	Greater persistence was observed after critical feedback.
Reflective Thinking	"Looking back, I now see what I could've done better and why."	The depth of student design justifications improved over time.
Collaboration	"Working with peers made it easier to expand on ideas I wouldn't have thought of."	Increased peer-to-peer feedback and iterative group discussions were observed.

In terms of instructional strategies, students responded positively to the combination of structured techniques and exploratory freedom. For example, while brainstorming and association techniques provided a framework to generate ideas, they appreciated being given the autonomy to select methods that best suited their design problem. The ability to personalize the process was highlighted as an important motivator and source of confidence, which supports previous findings that student agency contributes significantly to creative performance (Aldig & Arseven, 2017).

Challenges were also documented, particularly during the Experiment and Evaluation stages. Some students reported difficulty translating abstract ideas into physical models due to technical limitations or unfamiliarity with tools. Others struggled with receiving negative feedback during usability testing. These issues underscore the need for additional scaffolding, particularly in technical training and feedback literacy, to prepare students for constructive critique and iterative development. Educators must therefore balance cognitive stimulation with emotional resilience training, especially when working with novice designers.

An additional strength of the model is its adaptability to various instructional contexts. Although developed for interior design, the DIIEE model's theoretical foundations make it suitable for other creative disciplines, such as architecture, product design, or even visual communication. This cross-disciplinary applicability enhances the pedagogical value and scalability of the model in vocational and higher education settings. Its emphasis on innovation, emotional resonance, and iterative learning aligns with 21st-century skills required by both industry and society at large (Guo & Deng, 2020).

Figure 3 illustrates the process flow from the DIIEE stages concerning the expected learning outcomes and instructional strategies used at each phase. **Figure 3** serves as a pedagogical map for educators aiming to implement the model. It clearly outlines how each stage connects to specific competencies (e.g., fluency, originality) and instructional techniques (e.g., mind-mapping, prototyping). This transparency supports curriculum planning, enabling instructors to monitor students' development while offering timely support and reflection prompts. The cyclical design of the model, with feedback loops at each stage, also reinforces the non-linear nature of the design process, allowing students to revisit earlier stages based on feedback or new insights.

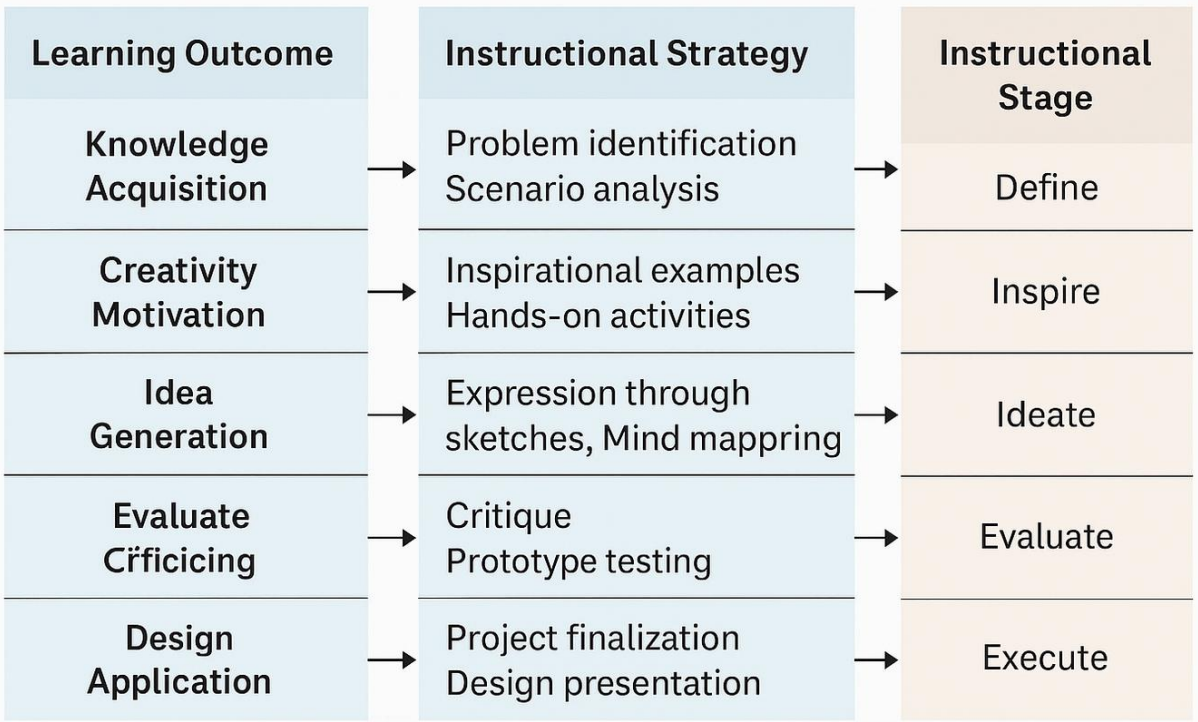

Figure 3. Instructional flow of the DIIEE model aligned with learning outcomes and strategies.

The evaluation phase, often overlooked in conventional design instruction, was given particular emphasis in this model. Students were taught not only to present their design but also to critically analyze its effectiveness from the perspective of emotional engagement, functionality, and user feedback. This reflective practice not only improved the quality of final outputs but also fostered design metacognition, a skill crucial for lifelong learning in creative fields (Xu, 2021).

Importantly, the study's findings offer concrete insights into instructional innovation in vocational design education, particularly in the Chinese context, where standardized instruction and exam-oriented learning still dominate many classrooms. By embedding creativity as a structured and assessable learning outcome, the study challenges the perception that innovation is an innate talent rather than a skill that can be systematically cultivated.

Moreover, the structured measurement using the Williams Creative Thinking Test provided reliable data to support qualitative observations. The increased scores in all four indicators post-intervention offer strong evidence of the model's effectiveness. These findings resonate with previous studies that emphasized the importance of combining qualitative and quantitative data in instructional research to offer a holistic understanding of learning processes and outcomes (Zang, 2018).

Finally, the DIIEE model's strength lies in its integration of multiple learning dimensions—cognitive, emotional, and social—into a cohesive framework. It moves beyond fragmented instructional approaches by treating students as whole individuals, addressing both what they learn and how they feel while learning. This integrative philosophy aligns well with global education trends advocating for human-centered, competency-based, and experience-rich pedagogies.

The sustainability and transferability of the instructional model were further examined through a post-semester workshop involving both students and instructors. During the session, participants were invited to evaluate the DIIEE model's potential for application in

future semesters and other creative design courses. The majority expressed enthusiasm for continuing the approach, citing increased motivation, meaningful engagement, and the sense of ownership they felt over their learning.

One student commented that the model helped them "think like a designer" rather than merely completing assignments. This statement reinforces the idea that when learners are empowered to explore and define problems, they begin to internalize the identity and habits of a creative professional, a goal that many design educators aspire to (Boucharenc, 2006). This development of identity is a hallmark of transformative learning, wherein students reframe how they view themselves, their discipline, and their potential.

Moreover, several instructors noted that the model encouraged them to rethink their teaching practices. By shifting from content transmission to process facilitation, they observed that students became more proactive and less dependent on the teacher as the sole source of knowledge. This shift echoes constructivist pedagogy principles, where the instructor's role is to support, not dictate, the learning journey.

While the impact of the model on students was consistently positive, a few limitations were identified. First, the time-intensive nature of project-based learning made it challenging to align with a tightly scheduled semester. Second, students with weak collaboration skills or limited access to prototyping tools faced steeper learning curves. These observations suggest that future implementations of the model should include built-in supports, such as collaboration training, technical workshops, or modular access to design tools and digital platforms.

In addition, students' emotional responses to critique varied significantly. While some embraced feedback as part of the creative process, others felt discouraged by negative evaluations, even when constructive. To address this, the research team recommends incorporating feedback training modules into the early weeks of instruction. These modules would help students understand the purpose of critique, develop emotional resilience, and learn strategies to interpret and apply feedback effectively.

To assess how the model contributed to specific skill sets, a follow-up survey was administered to students after the final submission. The results of the survey are presented next in Table 5. The most significant self-reported gains were in originality (82%), empathy (78%), and flexibility (74%). Fewer students (61%) reported strong development in precision, which aligns with earlier findings regarding prototyping challenges. Interestingly, the high scores in empathy reflect the success of embedding emotional design components within each stage of the model, confirming its effectiveness in bridging cognitive and affective design domains.

Furthermore, the development of empathy as a measurable skill highlights the growing importance of affective competencies in creative education, especially in disciplines where design outcomes must respond to real human contexts (Edmondson *et al*., 2020; Giangrande *et al*., 2019). By encouraging students to frame design not only as an intellectual task but also as a social and emotional one, the model expands the scope of traditional creativity instruction.

Another insight emerged from comparative analysis with previous cohorts that followed a more conventional curriculum. When comparing course evaluation forms, students who experienced the DIIEE model rated their sense of creativity and personal growth higher than those in traditional lecture-based formats. Although this evidence is anecdotal, it suggests that student perception of learning quality may also be positively influenced by constructivist and emotionally engaging pedagogies.

Additionally, the cyclical structure of the model promoted ongoing reflection. Students were not required to wait until final presentations to evaluate their work. Instead, through embedded reflection points after each phase, they engaged in continuous metacognition, enhancing their ability to self-correct, adapt, and improve. This reflective practice not only enhanced academic learning outcomes but also contributed to students' personal growth and confidence as emerging professionals.

Table 5. Student self-assessment of skill development after applying the DIIEE model.

Skill Area	Percentage of Students Reporting Improvement	Qualitative Feedback Examples
Emotional Awareness	87%	"I became more aware of how emotions affect my design decisions."
Creative Problem-Solving	92%	"This method helped me find new ideas I wouldn't have considered."
Empathy in Design	90%	"I now think more about how users feel, not just what they need."
Risk-Taking and Experimentation	85%	"I felt more confident trying out unconventional design approaches."
Reflective Thinking	88%	"I learned to evaluate my work more critically and constructively."

The highest perceived gains were in originality and emotional engagement, followed by empathy and flexibility. Fluency and precision scored lower, which can be attributed to the students' ongoing adjustment to the open-ended nature of the assignments and unfamiliar technical demands. These insights are invaluable for refining the instructional design by identifying which areas require additional scaffolding and support.

Taken together, the data suggest that the DIIEE model effectively supported the development of core competencies in innovative thinking, particularly in areas that are often underdeveloped in standard curricula. While fluency and precision can be enhanced with additional exercises and technical practice, the cultivation of empathy and originality is more challenging and thus marks a significant achievement of this instructional design.

The findings also contribute to the broader discourse on education for innovation in design and art-based programs. In many educational contexts (particularly those influenced by rigid curriculum standards and rote learning), creativity is often marginalized in favor of discipline and technical mastery. This study challenges that paradigm by demonstrating that creative competencies can be explicitly taught, practiced, and evaluated when supported by the right pedagogical framework.

From a theoretical standpoint, the DIIEE model represents an integrated approach to design pedagogy. It blends emotional design theory, constructivist learning principles, and the cognitive components of creative thinking into a structured yet adaptable instructional process. Its value lies not only in its practical success with students but also in its conceptual coherence, which makes it a viable model for replication, adaptation, and further research.

Moreover, the model aligns well with national education goals in China that emphasize innovative capacity, critical thinking, and emotional intelligence as key 21st-century learning outcomes (Maoulida *et al*., 2023). As such, this study provides timely insights into how these goals can be operationalized in real classroom settings, especially within vocational and applied design education.

In evaluating the long-term implications of the DIIEE instructional model, the study team also considered how the model may contribute to students' future readiness and adaptability in dynamic professional environments. The final interviews revealed that many students felt better equipped not only to generate ideas but also to adapt to new challenges, manage ambiguity, and navigate group dynamics. These are essential attributes in creative industries, where projects are often ill-defined and require both individual initiative and collaborative skills.

A key element identified in enabling this readiness was the iterative nature of the model. Unlike traditional linear approaches that emphasize output over process, the DIIEE model continually cycles students through idea generation, experimentation, evaluation, and reflection. This reinforces an adaptive learning mindset, encouraging students to become comfortable with failure and uncertainty, an essential disposition in design wor.

Moreover, the integration of emotional design and user empathy into every stage challenged students to reimagine creativity not as self-expression alone, but as relational and responsive practice. This marks a significant pedagogical shift, aligning with contemporary views of creativity as a social process involving perspective-taking, negotiation, and emotional intelligence (Celume & Zenasni, 2022).

Instructors also observed a transformation in classroom dynamics. The studio became less hierarchical and more dialogic, with students initiating discussions, providing peer feedback, and sharing insights from diverse backgrounds. This transformation underscores how pedagogical models that value student agency and emotional engagement can foster inclusive, equitable learning environments, especially in fields where innovation emerges from diverse perspectives.

Nevertheless, institutional factors remain a consideration. While the model was successfully implemented in the context of a research university with access to resources and instructor autonomy, challenges may arise in more rigid institutional settings (Gonsharuk & Cirella, 2022). Educators wishing to implement this model in different contexts will need to negotiate constraints such as curriculum flexibility, assessment systems, instructor readiness, and available facilities (Omwenga *et al*., 2004). A phased implementation or pilot program could be a pragmatic starting point.

From a research perspective, this study contributes to the growing body of work on creativity and design education in non-Western contexts. Much of the literature on instructional models for innovation is based in Western educational systems, and there is a need for localized, culturally relevant models that address the unique challenges and opportunities of other regions. The DIIEE model, while theoretically grounded in universal principles of creativity, was constructed with direct reference to the learning cultures and systemic structures found in Chinese higher education. Thus, this model may serve as a template for further contextualization in similar educational settings across Asia or other parts of the world where design education is growing rapidly but still negotiating the tension between traditional instruction and modern creative imperatives. Furthermore, the study reflects the value of combining quantitative and qualitative methodologies in pedagogical research. The use of validated creative thinking assessments, alongside rich descriptive data from observations, interviews, and reflections, provides a multi-dimensional understanding of learning outcomes. This mixed-methods approach offers both breadth and depth, ensuring that both measurable skills and less tangible changes (e.g., mindset, motivation, identity) are captured.

Table 6 consolidates the key outcomes and pedagogical implications drawn from this study. The DIIEE model yielded benefits across three major domains: (i) student competencies, (ii) instructional effectiveness, and (iii) pedagogical transformation. Among the competencies, originality, empathy, and emotional engagement stood out as the most developed. Instructionally, the model fostered sustained engagement, improved peer learning, and enhanced reflective practice. Pedagogically, the shift from product-oriented teaching to process-centered learning emerged as the most significant transformation.

Table 6. Summary of key findings and instructional implications of the DIIEE model.

Key Finding	Instructional Implication
Emotional design enhances student engagement.	Integrate affective elements into design briefs and project framing.
Empathy fosters deeper user-centered innovation.	Include empathy mapping and persona development in the early stages of instruction.
Iterative prototyping builds creative confidence.	Allow flexible, low-risk experimentation through ongoing feedback.
Reflection supports metacognitive growth.	Embed structured self and peer assessment opportunities throughout the design process.
Collaborative learning enriches ideation quality.	Facilitate group brainstorming and interdisciplinary design discussions.

Taken together, these findings validate the theoretical foundations of the model and affirm its practical utility in real-world teaching scenarios. The DIIEE model offers a comprehensive, integrative framework that can serve not only as a course-specific strategy but also as a guiding philosophy for curriculum design in creative fields.

Looking forward, the research team proposes several directions for future study. First, longitudinal research should be conducted to examine how the competencies developed through this model influence students' performance in professional settings or advanced academic work. Second, comparative studies across different cultural and institutional contexts can help refine the model's universal and contextual features. Third, exploring the model's application in online or hybrid learning environments could extend its relevance, especially in light of the growing digital transformation in education.

Moreover, as design education increasingly intersects with global sustainability goals, it may be worthwhile to investigate how the DIIEE model can incorporate social responsibility and environmental consciousness as explicit learning objectives. Adding a sustainability dimension could enhance the moral and civic aspects of innovation, which are becoming crucial in 21st-century design practices.

Lastly, the DIIEE model opens pathways for teacher professional development. Designing training modules that equip educators with the tools, mindset, and facilitation strategies to apply the model effectively is a natural next step. Supporting teachers through collaborative communities of practice can ensure that the model is not merely adopted as a technique but internalized as a pedagogical orientation.

In conclusion, this study demonstrates that innovation in education (particularly in creative disciplines) requires more than just new content or tools. It demands a reimagining of the learning process as one that is iterative, emotionally engaged, and socially embedded. The DIIEE instructional model meets this challenge by offering a structured yet flexible pathway for cultivating students' innovative thinking in ways that are rigorous, relational, and transformative.

By fostering a learning environment where students are empowered to explore, fail, empathize, and reflect, the model not only prepares them to become designers of creative solutions but also designers of their learning journeys and professional futures.

Finally, the implementation of the DIIEE instructional model aligns with the principles of SDG 4: Quality Education, which emphasizes inclusive and equitable quality education and the promotion of lifelong learning opportunities for all. By fostering innovative thinking, emotional engagement, and interdisciplinary collaboration, the model cultivates not only technical and creative competencies but also critical soft skills such as empathy, communication, and reflective learning. These competencies are essential for preparing students to contribute meaningfully to sustainable practices within the design industry, particularly in environmental art and interior architecture. Furthermore, the model encourages project-based learning that often incorporates real-world sustainability challenges, thereby enabling learners to engage directly with the complexities of responsible design in a rapidly evolving global context. This study is in line with current issues in SDGs as reported elsewhere (**Table 7**).

Table 7. Previous studies on SDGs

No	Title	Reference
1	Low-carbon food consumption for solving climate change mitigation: Literature review with bibliometric and simple calculation application for cultivating sustainability consciousness in facing sustainable development goals (SDGs)	Nurramadhani *et al*. (2024)
2	Towards sustainable wind energy: A systematic review of airfoil and blade technologies over the past 25 years for supporting sustainable development goals (SDGs)	Krishnan *et al*. (2024)
3	Assessment of student awareness and application of eco-friendly curriculum and technologies in Indonesian higher education for supporting sustainable development goals (SDGs): A case study on environmental challenges	Djirong *et al*. (2024)
4	A study on sustainable eggshell-derived hydroxyapatite/CMC membranes: Enhancing flexibility and thermal stability for sustainable development goals (SDGs)	Waardhani *et al*. (2025)
5	Integrating multi-stakeholder governance, engineering approaches, and bibliometric literature review insights for sustainable regional road maintenance: Contribution to sustainable development goals (SDGs) 9, 11, and 16	Yustiarini *et al*. (2025)
6	Computational engineering of malonate and tetrazole derivatives targeting SARS-CoV-2 main protease: Pharmacokinetics, docking, and molecular dynamics insights to support the sustainable development goals (SDGs), with a bibliometric analysis	Merzouki *et al*. (2025)
7	Innovative nanofluid encapsulation in solar stills: Boosting water yield and efficiency under extreme climate, supporting sustainable development goals (SDGs)	Namoussa *et al*. (2025)
8	Modernization of submersible pump designs for sustainable irrigation: A bibliometric and experimental contribution to sustainable development goals (SDGs)	Glovatskii *et al*. (2025)
9	Sustainable development goals (SDGs) in engineering education: Definitions, research trends, bibliometric insights, and strategic approaches	Ragadhita *et al*. (2026)

Table 7 (continue). Previous studies on SDGs

No	Title	Reference
10	Sustainable packaging: Bioplastics as a low-carbon future step for the sustainable development goals (SDGs)	Basnur *et al*. (2024)
11	Production of wet organic waste ecoenzymes as an alternative solution for environmental conservation supporting sustainable development goals (SDGs): A techno-economic and bibliometric analysis.	Sesrita *et al*. (2025)
12	Hazard identification, risk assessment, and determining control (HIRADC) for workplace safety in the manufacturing industry: A risk-control framework complete with bibliometric literature review analysis to support sustainable development goals (SDGs)	Henny *et al*. (2025)
13	Techno-economic analysis of production ecobrick from plastic waste to support sustainable development goals (SDGs)	Syahrudin *et al*. (2026)
14	Techno-economic analysis of sawdust-based trash cans and their contribution to Indonesia's green tourism policy and the sustainable development goals (SDGs)	Apriliani *et al*. (2026)
15	The influence of environmentally friendly packaging on consumer interest in implementing zero waste in the food industry to meet sustainable development goals (SDGs) needs	Haq *et al*. (2024)
16	Effect of substrate and water on cultivation of Sumba seaworm (nyale) and experimental practicum design for improving critical and creative thinking skills of prospective science teacher in biology and supporting sustainable development goals (SDGs)	Kerans *et al*. (2024)
17	Characteristics of jengkol peel (Pithecellobium jiringa) biochar produced at various pyrolysis temperatures for enhanced agricultural waste management and supporting sustainable development goals (SDGs)	Rahmat *et al*. (2024)
18	Contributing factors to greenhouse gas emissions in agriculture for supporting sustainable development goals (SDGs): Insights from a systematic literature review completed by computational bibliometric analysis	Soegoto *et al*. (2025)
19	The relationship of vocational education skills in agribusiness processing agricultural products in achieving sustainable development goals (SDGs)	Gemil *et al*. (2024)
20	Sustainable development goals (SDGs) in science education: Definition, literature review, and bibliometric analysis	Maryanti *et al*. (2022)

5. CONCLUSION

The DIIEE instructional model effectively enhanced students' innovative thinking by integrating emotional design, constructivism, and iterative creative processes. Students demonstrated growth in originality, empathy, and design adaptability through emotionally engaging, user-centered learning experiences. The model fostered a reflective, collaborative studio environment that aligned theory with practice. Its application revealed strong pedagogical potential and contextual relevance for creative education. Future adaptation in diverse educational settings may further affirm its value in cultivating innovation competencies essential for 21st-century design professionals.

6. ACKNOWLEDGMENTS

This study is supported by Mahasarakham University, Mahasarakham, Thailand.

7. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

8. REFERENCES

Adebayo, A.E., and Ochayi, O.A. (2022). Utilization of internet services among students of polytechnic institutions in Kwara State. *Indonesian Journal of Multidiciplinary Research*, *2*(1), 27-42.

Aldig, E., and Arseven, A. (2017). The contribution of learning outcomes for listening to creative thinking skills. *Journal of Education and Learning*, *6*(3), 41–53.

Anjum, G., and Bhatti, M.A.A. (2024). Discover the impact of internet usage on the academic performance of library and information science students. *Indonesian Journal of Multidiciplinary Research*, *4*(2), 377-388.

Apriliani, A., Waahyudin, C., Ramdani, F.T., Martin, A.Y., Syahrudin, D., Hernawan, D., and Salbiah, E. (2026). Techno-economic analysis of sawdust-based trash cans and their contribution to Indonesia's green tourism policy and the sustainable development goals (SDGs). *ASEAN Journal for Science and Engineering in Materials*, *5*(1), 17-36.

Awalussillmi, I., Febriyana, K.R., Padilah, N., and Saadah, N.A. (2023). Efforts to improve sustainable development goals (SDGs) through education on diversification of food using infographic: Animal and vegetable protein. *ASEAN Journal of Agricultural and Food Engineering*, *2*(2), 113-120.

Basnur, J., Putra, M.F.F., Jayusman, S.V.A., and Zulhilmi, Z. (2024). Sustainable packaging: Bioplastics as a low-carbon future step for the sustainable development goals (SDGs). *ASEAN Journal for Science and Engineering in Materials*, *3*(1), 51-58.

Boucharenc, C. G. (2006). Research on basic design education: An international survey. *International Journal of Technology and Design Education*, *16*, 1–30.

Celume, M. P., and Zenasni, F. (2022). How perspective-taking underlies creative thinking and the socio-emotional competency in trainings of drama pedagogy. *Estudos de Psicologia (Campinas)*, *39*, e200015.

Chin, C., and Osborne, J. (2010). Students' questions and discursive interaction: Their impact on argumentation during collaborative group discussions in science. *Journal of research in Science Teaching*, *47*(7), 883-908.

Djirong, A., Jayadi, K., Abduh, A., Mutolib, A., Mustofa, R.F., and Rahmat, A. (2024). Assessment of student awareness and application of eco-friendly curriculum and technologies in Indonesian higher education for supporting sustainable development goals (SDGs): A case study on environmental challenges. *Indonesian Journal of Science and Technology*, *9*(3), 657-678.

Dwyer, C. P., Hogan, M. J., and Stewart, I. (2014). An integrated critical thinking framework for the 21st century. *Thinking Skills and Creativity*, *12*, 43-52.

Edmondson, J., Formica, P., and Mitra, J. (2020). Empathy, sensibility and graduate employment–Can the humanities help?. *Industry and Higher Education*, *34*(4), 223-229.

Fadillah, P., Nandiyanto, A.B.D., Kurniawan T., and Bilad, M.R. (2022). Internet literature: Increasing information competence in the learning process of students of class 7 middle school. *Indonesian Journal of Educational Research and Technology*, *2*(2), 81-86.

Fokkinga, S., Desmet, P., and Hekkert, P. (2020). Impact-centered design: Introducing an integrated framework of the psychological and behavioral effects of design. *International Journal of Design*, *14*(3), 97.

Gemil, K.W., Na'ila, D.S., Ardila, N.Z., and Sarahah, Z.U. (2024). The relationship of vocational education skills in agribusiness processing agricultural products in achieving sustainable development goals (SDGs). *ASEAN Journal of Science and Engineering Education*, *4*(2), 181-192.

Giangrande, N., White, R. M., East, M., Jackson, R., Clarke, T., Saloff Coste, M., and Penha-Lopes, G. (2019). A competency framework to assess and activate education for sustainable development: Addressing the UN sustainable development goals 4.7 challenge. *Sustainability*, *11*(10), 2832.

Glovatskii, O., Kalimbetov, B., Ergashev, R., Kholbutaev, B., Pardaev, M., Ergasheva, G., Nasirova, N., and Khimmataliev, D.O. (2025). Modernization of submersible pump designs for sustainable irrigation: A bibliometric and experimental contribution to sustainable development goals (SDGs). *Indonesian Journal of Science and Technology*, *10*(3), 427-438.

Glushchenko, V.V. (2023). Ergodesign and "specific", "measurable", "achievable", "relevant", and "time-bound" (SMART) technologies as tools for the formation of innovative leadership programs. *ASEAN Journal of Economic and Economic Education*, *2*(1), 23-34.

Goncharuk, A. G., and Cirella, G. T. (2022). Effectiveness of academic institutional models in Europe: University instructor perception case research from Bosnia and Herzegovina and France. *International Journal of Educational Management*, *36*(5), 836-853.

Guo, J., and Deng, F. (2020). The impact of talent training reform in colleges and universities on the innovation ability of college students. *Higher Education Research*, *41*(07), 70–77.

Haq, M.R.I., Nurhaliza, D.V., Rahmat, L.N., and Ruchiat, R.N.A. (2024). The influence of environmentally friendly packaging on consumer interest in implementing zero waste in the food industry to meet sustainable development goals (SDGs) needs. *ASEAN Journal of Economic and Economic Education*, *3*(2), 111-116.

Henny, H., Budi, A.H.S., Andriyansyah, M., Ar Rozzak, M.R., Baru, M.M., and Masek, A. (2025). Hazard identification, risk assessment, and determining control (HIRADC) for workplace safety in manufacturing industry: A risk-control framework complete with bibliometric literature review analysis to support sustainable development goals (SDGs). *ASEAN Journal for Science and Engineering in Materials*, *4*(2), 267-284.

Hernández-Leo, D., Asensio-Pérez, J. I., Derntl, M., Pozzi, F., Chacón, J., Prieto, L. P., and Persico, D. (2018). An integrated environment for learning design. *Frontiers in ICT*, *5*, 9.

Juvova, A., Chudy, S., Neumeister, P., Plischke, J., and Kvintova, J. (2015). Reflection of constructivist theories in current educational practice. *Universal Journal of Educational Research*, *3*(5), 345-349.

Keisyafa, A., Sunarya, D.N., Aghniya, S.M., and Maula, S.P. (2024). Analysis of student's awareness of sustainable diet in reducing carbon footprint to support Sustainable Development Goals (SDGs) 2030. *ASEAN Journal of Agricultural and Food Engineering*, *3*(1), 67-74.

Kerans, G., Sanjaya, Y., Liliasari, L., Pamungkas, J., and Ate, G., Y. (2024). Effect of substrate and water on cultivation of Sumba seaworm (nyale) and experimental practicum design for improving critical and creative thinking skills of prospective science teacher in biology and supporting sustainable development goals (SDGs). *ASEAN Journal of Science and Engineering*, *4*(3), 383-404.

Krishnan, A., Al-Obaidi, A.S.M., and Hao, L.C. (2024). Towards sustainable wind energy: A systematic review of airfoil and blade technologies over the past 25 years for supporting sustainable development goals (SDGs). *Indonesian Journal of Science and Technology*, *9*(3), 623-656.

Liu, J., Zhang, C., Qiao, Y., Li, H., and Jiang, Z. (2020). Application of TRIZ theory in product design course teaching for industrial design majors. *Curriculum Education Research*, *2020*(03), 253–254.

Maoulida, H., Madhukar, M., and Celume, M. P. (2023). A case study of 21st century cognitive, social and emotional competencies using online-learning. *Journal of Intelligence*, *11*(6), 116.

Maryanti, R., Rahayu, N., Muktiarni, M., Al Husaeni, D. F., Hufad, A., Sunardi, S., and Nandiyanto, A. B. D. (2022). Sustainable development goals (SDGs) in science education: Definition, literature review, and bibliometric analysis. *Journal of Engineering Science and Technology*, *17*, 161-181.

Maulana, I., Asran, M.A., and Ash-Habi, R.M. (2023). Implementation of Sustainable Development Goals (SDGs) no. 12: Responsible production and consumption by optimizing lemon commodities and community empowerment to reduce household waste. *ASEAN Journal of Community Service and Education*, *2*(2), 141-146.

Merzouki, M., Khibech, O., Fraj, E., Bouammali, H., Bourhou, C., Hammouti, B., Bouammali, B., and Challioui, A. (2025). Computational engineering of malonate and tetrazole derivatives targeting SARS-CoV-2 main protease: Pharmacokinetics, docking, and molecular dynamics insights to support the sustainable development goals (SDGs), with a bibliometric analysis. *Indonesian Journal of Science and Technology*, *10*(2), 399-418.

Mirattanaphrai, P., and Srikoon, S. (2025). Design and development of innovator self-assessment questionnaire for students in grade 6: Utilizing educational design research. *Social Sciences & Humanities Open*, *11*, 101414.

Namoussa, T.Y., Boucerredj, L., Khechekhouche, A., Kemerchou, I., Zair, N., Jahangiri, M., Miloudi, A., and Siqueira, A. (2025). Innovative nanofluid encapsulation in solar stills: Boosting water yield and efficiency under extreme climate supporting sustainable development goals (SDGs). *Indonesian Journal of Science and Technology*, *10*(3), 419-426.

Nasser, M. A. (2024). Beyond the Canvas: An Exploration of Curriculum Design and Aesthetic Education in Fostering Aesthetic Development and Artistic Skills among Primary School Students. *Journal of Advanced Research in Social Sciences and Humanities*, *9*(1), 15-33.

Nurnabila, A.T., Basnur, J., Rismayani, R., Ramadhani, S., and Zulhilmi, Z. (2023). Analysis of the application of Mediterranean diet patterns on sustainability to support the achievement of sustainable development goals (SDGs): Zero hunger, good health and well beings, responsible consumption, and production. *ASEAN Journal of Agricultural and Food Engineering*, *2*(2), 105-112.

Nurramadhani, A., Riandi, R., Permanasari, A., and Suwarma, I.R. (2024). Low-carbon food consumption for solving climate change mitigation: Literature review with bibliometric and simple calculation application for cultivating sustainability consciousness in facing sustainable development goals (SDGs). *Indonesian Journal of Science and Technology*, *9*(2), 261-286.

Omwenga, E., Waema, T., and Wagacha, P. (2004). A model for introducing and implementing e-learning for delivery of educational content within the African context. *African Journal of Sciences and Technology*, *5*(1), 35-48.

Prasojo, L.D., Yuliana, L., and Prihandoko, L.A. (2025). Research performance in higher education: A PLS-SEM analysis of research atmosphere, collaboration, funding, competence, and output, especially for science and engineering facilities in Indonesian universities. *ASEAN Journal of Science and Engineering*, *5*(1), 123-144.

Rababah, L. (2018). An adapted version of Torrance Test of Creative Thinking (TTCT) In EFL/ESL writing: A rubric scoring and a review of studies. *International Journal of English and Education*, *7*(2), 128-136.

Ragadhita, R., Fiandini, M., Al Husaeni, D.N., and Nandiyanto, A.B.D. (2026). Sustainable development goals (SDGs) in engineering education: Definitions, research trends,

bibliometric insights, and strategic approaches. *Indonesian Journal of Science and Technology*, *11*(1), 1-26.

Rahmah, F.A., Nurlaela, N., Anugrah, R., and Putri, Y.A.R. (2024). Safe food treatment technology: The key to realizing the Sustainable Development Goals (SDGs) zero hunger and optimal health. *ASEAN Journal of Agricultural and Food Engineering*, *3*(1), 57-66.

Rahmat, A., Zahrani, A., Hidayat, H., Arum, F., Respati, S.A., Susanti, W.D., Hariadi, H., Mutolib, A. (2025). Characteristics of jengkol peel (Pithecellobium jiringa) biochar produced at various pyrolysis temperatures for enhanced agricultural waste management and supporting sustainable development goals (SDGs). *ASEAN Journal of Science and Engineering*, *5*(1), 145-172.

Rickey, N., Dubek, M., and DeLuca, C. (2023). Toward a praxis-oriented understanding of student self-assessment in STEAM education: How exemplary educators leverage self-assessment. *Cambridge Journal of Education*, *53*(5), 605-625.

Sesrita, A., Adri, H.T., Suherman, I., Rasmitadila, R., and Fanani, M.Z. (2025). Production of wet organic waste ecoenzymes as an alternative solution for environmental conservation supporting sustainable development goals (SDGs): A techno-economic and bibliometric analysis. *ASEAN Journal for Science and Engineering in Materials*, *4*(2), 245-266.

Soegoto, H.S., Pohan, M.A.R., Luckyardi, S., Supatmi, S., Amasawa, E., Phithakkitnukoon, S., and Hasibuan, Z.A. (2025). Contributing factors to greenhouse gas emissions in agriculture for supporting sustainable development goals (SDGs): Insights from a systematic literature review completed by computational bibliometric analysis. *ASEAN Journal of Science and Engineering*, *5*(2), 199-230

Syahrudin, D., Roestamy, M., Fauziah, R.S.P., Rahmawati, R., Pratidina, G., Purnamasari, I., Muhtar, S., and Salbiah, E. (2026). Techno-economic analysis of production ecobrick from plastic waste to support sustainable development goals (SDGs). *ASEAN Journal for Science and Engineering in Materials*, *5*(1), 9-16.

Waardhani, A.W., Noviyanti, A.R., Kusrini, E., Nugrahaningtyas, K.D., Prasetyo, A.B., Usman, A., Irwansyah, F.S., and Juliandri, J. (2025). A study on sustainable eggshell-derived hydroxyapatite/CMC membranes: Enhancing flexibility and thermal stability for sustainable development goals (SDGs). *Indonesian Journal of Science and Technology*, *10*(2), 191-206.

Wang, L. (2022). Student intrinsic motivation for online creative idea generation: Mediating effects of student online learning engagement and moderating effects of teacher emotional support. *Frontiers in Psychology*, *13*, 954216.

Xu, D. (2018). Exploration of the path of cultivating innovative thinking of college students. *Innovation and Entrepreneurship Education*, *9*(2), 19–22.

Yu, Q., and Nagai, Y. (2020). A new approach to teaching emotional design. *Social Sciences*, *9*(11), 210.

Yustiarini, D., Soemardi, B.W., and Pribadi, K.S. (2025). Integrating multi-stakeholder governance, engineering approaches, and bibliometric literature review insights for sustainable regional road maintenance: Contribution to sustainable development goals (SDGs) 9, 11, and 16. *Indonesian Journal of Science and Technology*, *10*(2), 367-398.

Zang, Q. (2018). Strategies for cultivating students' creative thinking in industrial design teaching in colleges and universities. *University Education*, *2018*(06), 162–164.