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The TABS model: integrating *Tadabbur Alam*, biomimicry, and STEAM to foster students' sustainability awareness and creative problem-solving skills

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Abstract

Higher education in the 21st century is expected to produce graduates who are not only intellectually excellent but also possess reflective spirituality, sustainability awareness (SusNess), and Creative Problem-Solving Skills (CREPs). However, science learning practices in universities still tend to focus on cognitive aspects, thus lacking in fostering spiritual reflection, ecological empathy, and sustainable action. This study aims to develop the design of the *Tadabbur Alam-Biomimicry-STEAM* (TABS) learning model, which integrates the *Tadabbur Alam*, Biomimicry, and STEAM approaches to cultivate reflective, creative, and sustainability-oriented students. The method used is a Systematic Literature Review (SLR) of 63 published scientific articles from 2015–2025 that are relevant to science education and Education for Sustainable Development (ESD). The findings indicate that integrating *Tadabbur Alam*, Biomimicry, and STEAM effectively enhances students' scientific creativity, ecological empathy, and spiritual reflection. These three approaches complement one another in fostering SusNess through value reflection and contextual experiences, as well as developing CREPs through sustainable scientific innovation. The synthesis results in an eight-stage TABS model that combines observation, reflection, innovation, and sustainable action, offering a holistic and contextual science learning framework to strengthen Education for Sustainable Development (ESD) in higher education.

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Introduction

Higher education in the 21st century is required to prepare a generation that excels not only academically but also possesses strong problem-solving abilities, ecological awareness, and spiritual depth. The modern world is facing a multidimensional crisis, including environmental degradation, moral decline, and the erosion of humanitarian values. Although technological progress has improved human life, it has also accelerated the exploitation of natural resources and weakened the spiritual connection between humans and nature. In this context, Education for Sustainable Development (ESD) promoted by UNESCO (2025) emphasizes the importance of integrating knowledge, skills, values, and actions to foster sustainable behavior. Higher education thus plays a strategic role in bridging scientific rationality with moral

consciousness—shaping future scientists and educators who are not only intellectually capable but also ethical and responsible for the sustainability of life.

However, the implementation of ESD in developing countries, including Indonesia, still faces structural and paradigmatic challenges. Spiritual values and local wisdom, which are the cultural strengths of the nation, have not yet been fully integrated into educational practices. In fact, approaches such as *Tadabbur Alam* (nature contemplation) can serve as a distinctive feature of Indonesian education, harmonizing science, values, and faith. From an Islamic perspective, nature is not merely an object of empirical observation but a cosmic text containing divine messages (Al-zamakhshari, 2024; Cholidi, 2022; Khairani et al., 2024). The relationship between humans, nature, and God forms an interrelated epistemological system: humans, as *khalifah* (stewards), are entrusted to manage nature wisely, while scientific knowledge functions as a bridge to understand the greatness of the Creator (Karimullah, 2023). Therefore, science education must cultivate awareness that every natural phenomenon holds moral and spiritual values, enabling students to solve problems creatively, wisely, and with a sustainable worldview.

Unfortunately, the actual conditions of learning in many universities reveal a gap between those ideals and classroom practice. Field observations show that students in the Science Education Program (Tadris IPA) at UIN Sunan Kudus tend to be passive during learning, struggle to connect scientific concepts with real-world problems, and demonstrate limited Sustainability Awareness (SusNess), which refers briefly to students' awareness, attitudes, and sustainable actions related to ecological, social, and economic responsibilities. In addition, students also exhibit low levels of Creative Problem-Solving Skills (CREPs), defined early as the ability to identify problems, generate ideas, select appropriate solutions, and apply them reflectively in real contexts. The dominance of lecture-based and cognitively oriented instruction has made students passive recipients of knowledge. Moreover, the lack of exploration, reflection, and contextual experiences hinders the optimal development of creative and reflective thinking skills.

Today's digital-native students face what is known as nature-deficit experience (a decline in direct interaction with nature due to the dominance of virtual life) which weakens their ecological sensitivity and empathy toward the environment (Battisti, 2024; Kumpulainen, 2019). As a result, science learning often loses its existential meaning, with nature understood only conceptually rather than experienced as a source of inspiration and wisdom. Direct engagement through observation, exploration, and reflection in nature is essential to foster students' ecological and spiritual awareness. Furthermore, university evaluation systems that remain focused primarily on cognitive outcomes narrow the definition of learning success by neglecting creative thinking processes, value reflection, and spiritual development. This condition risks producing scientists who are intellectually capable but lack ecological empathy and moral responsibility.

Research findings in Indonesia reinforce this reality. Beavington (2021) found that most science education students preferred classroom-based learning over field activities, indicating low engagement with natural phenomena. Other studies revealed that students who participated in spiritually grounded environmental projects showed significant improvements in ecological awareness and social responsibility (Muzakki et al., 2025; Roets & Ramirez, 2024; Rusli et al.,

2023). These findings highlight the urgent need for a learning model that integrates scientific inquiry, spiritual reflection, and ecological concern into a unified and contextualized educational framework.

To address these challenges, several innovative approaches have been developed in science education, including STEAM, Biomimicry, and *Tadabbur Alam*. Each approach contributes to different yet complementary dimensions of the learning process: STEAM fosters interdisciplinary creativity (Alves et al., 2019; Diego-Mantecon et al., 2021), Biomimicry cultivates ecological awareness and sustainable innovation (Irene, 2025; Tsu, 2025), while *Tadabbur Alam* strengthens spiritual reflection and moral responsibility toward God's creation (Reswari et al., 2025). Individuals who internalize these values are more likely to develop a conscious commitment to addressing environmental problems within their surroundings.

The STEAM approach emphasizes cross-disciplinary collaboration by integrating science, technology, and the arts as a means of fostering creative and contextual thinking. Cheung (2024) demonstrated that STEAM-based learning enhances students' critical thinking, creativity, scientific communication, and collaboration skills. This model provides learners with opportunities to express scientific ideas through aesthetic and innovative design approaches. By bridging science and art, STEAM enables students to connect scientific theory with real-world contexts, making learning more meaningful, applicable, and humanistic.

Furthermore, biomimicry emerges as an extension of the creative spirit of STEAM toward a deeper ecological awareness. Introduced by Benyus (1997), biomimicry promotes an ecological mindset that positions nature as a source of inspiration for sustainable innovation. This approach teaches students to learn from the adaptive strategies of living organisms in addressing modern human challenges. Every natural system operates efficiently, harmoniously, and sustainably without disrupting ecological balance (Fathin & Raida, 2025; Raida et al., 2023). Thus, biomimicry not only fosters appreciation for nature's wisdom but also develops systems thinking and environmentally responsible technological innovation (Kennedy, 2017). In the context of science education, biomimicry serves as a bridge between conceptual understanding and ethical application toward the environment.

If STEAM fosters interdisciplinary creativity and biomimicry cultivates ecological awareness, *Tadabbur Alam* serves to integrate spirituality and morality within the scientific process. *Tadabbur* refers to reflecting upon and understanding the signs of God's greatness through natural phenomena (*ayat kauniyah*)) (Hardinagoro et al., 2024; Nahdiyah et al., 2023). Through observation and reflection on God's creations, students are encouraged to discover order, harmony, and moral values behind scientific phenomena. This approach bridges scientific rationality with religious spirituality, integrating faith, knowledge, and practice (Alandika, 2022; Desanda, 2025). Thus, *Tadabbur Alam* not only enriches scientific understanding but also nurtures students' spiritual awareness and ecological responsibility as stewards (*khalifah*) of the Earth.

The three approaches (STEAM, Biomimicry, and *Tadabbur Alam*) represent three complementary dimensions of learning: scientific creativity, ecological innovation, and spiritual reflection. However, their implementation in higher education has been mostly partial and not yet integrated into a unified conceptual framework. Therefore, a transdisciplinary learning model is needed, one that can combine the reflective-spiritual strength of *Tadabbur*

Alam, the ecological-innovative perspective of Biomimicry, and the creative-interdisciplinary integration of STEAM into a comprehensive learning system. The integration of these three approaches results in the *Tadabbur Alam* Biomimicry STEAM (TABS) model, which focuses on developing students' Sustainability Awareness (SusNess) and Creative Problem-Solving Skills (CREPs). These are two essential 21st-century competencies that shape the profile of science graduates who are scientifically competent, sustainability-oriented, and capable of solving complex problems creatively and reflectively.

As introduced earlier, both SusNess and CREPs require further conceptual clarification to explain their full meaning and operational dimensions. SusNess is defined as a continuous awareness to preserve, protect, and appreciate the environment by considering its impact on ecological, social, and economic aspects (Raida et al., 2024). Operationally, this awareness consists of three key dimensions: (1) sustainability practice awareness, namely the ability to apply sustainable practices in daily life; (2) behavioral and attitude awareness, referring to awareness in forming positive behaviors and attitudes toward environmental issues; and (3) emotional awareness, which refers to emotional sensitivity toward personal responsibility for the condition of the surrounding environment (Raida, 2025). These three dimensions reflect a balance between knowledge, attitudes, and values that form the core of ESD. Through learning that integrates *Tadabbur Alam*, Biomimicry, and STEAM, students not only understand the scientific concepts of sustainability, but also foster empathy, concern, and moral commitment to protect the Earth consciously and sustainably.

Meanwhile, CREPs are higher-order thinking skills that integrate creativity, critical thinking, and analytical abilities to generate innovative solutions to complex problems (Amran et al., 2019; Wongklang & Wipatsopakron, 2024). Operationally, CREPs involve five stages of creative thinking: (1) problem identification to determine the root cause; (2) exploration of solution ideas through divergent thinking; (3) selection of the best solution by considering the context and available resources; (4) planning systematic problem-solving actions; and (5) implementation and evaluation of the solution based on its effectiveness in real-world situations (Osburn & Mumford, 2006; Puccio et al., 2012). This process connects divergent thinking, which generates multiple ideas, with convergent thinking, which selects and refines the most appropriate solution (Amran et al., 2019).

Thus, the integration of the three approaches in the TABS model not only shapes students to be creative in thinking and acting, but also cultivates a high level of awareness of their ecological and social responsibilities. TABS-based learning fosters two key 21st-century competencies: CREPs as a form of scientific and innovative thinking, and SusNess as the ethical and moral foundation for every scientific and social action. These two competencies complement each other. CREPs encourage students to generate real and innovative solutions (Amran et al., 2019), while SusNess ensures that every innovation is aligned with sustainability values and contributes to the welfare of life (Lathifah et al., 2024).

Several previous studies support the effectiveness of each approach independently. Rilianti et al., (2023) showed that STEAM enhances students' critical and collaborative thinking skills; Mejía-Villa et al. (2023) demonstrated that biomimicry fosters sustainable innovation; while Hardinagoro et al. (2024) found that *Tadabbur Alam* strengthens spirituality and ecological

responsibility. However, to date, no learning model has conceptually and operationally integrated these three approaches into a unified and transdisciplinary framework.

This gap is the focus of the present study. Until now, the spiritual, ecological, and creative dimensions have been developed separately in higher education, even though these three components are closely interconnected in shaping individuals who are knowledgeable and possess ecological ethics. Therefore, this study offers novelty in the form of the TABS model, which is oriented toward developing SusNess and CREPs. Thus, the TABS model is designed to cultivate students who think creatively, act reflectively, and are committed to environmental sustainability. The integration of these three approaches positions learning not only as a means of knowledge transfer, but also as a spiritual and moral experience that fosters ecological awareness.

To address this gap, the present study employs a Systematic Literature Review (SLR) approach with the aim of formulating the TABS model, which is oriented toward developing students' SusNess and CREPs. This review seeks to answer three main research questions: (1) how each of the three approaches has been implemented and what outcomes they produce in science learning, (2) how the three approaches are conceptually interconnected in developing students' SusNess and CREPs, and (3) how the synthesized literature can be utilized to design an operational and contextual TABS learning model.

Method

This study employed a Systematic Literature Review (SLR) method to systematically examine various research findings, theories, and concepts relevant to the development of the integrative TABS learning model. This approach was chosen because the objective of the study is not merely to describe theories, but to synthesize empirical and conceptual findings in order to construct a new learning framework oriented toward the development of students' SusNess and CREPs. SLR was considered the most appropriate method because it enables the systematic integration of diverse theoretical perspectives TABS which originate from different epistemological traditions. Through SLR, patterns, conceptual overlaps, and complementary relationships across studies can be identified, providing a rigorous evidence base for constructing a coherent and transdisciplinary learning model. In this way, SLR supports the development of a new integrative framework that is grounded in accumulated research findings rather than on isolated theoretical assumptions. The overall screening and selection procedures were conducted with inter-rater reliability checks to ensure consistency across reviewers.

The literature search was conducted systematically across several international and national databases, namely Scopus, Web of Science, ERIC, Google Scholar, and SpringerLink. The keywords used included "tadabbur nature-based learning," "biomimicry in education," STEAM approach in education," "creative problem-solving skills," "sustainability awareness," and "education for sustainable development." Boolean operators "AND" and "OR" were used to combine the keywords. The publication range reviewed was 2015–2025, covering a decade of development in innovative learning theories and sustainable education.

The inclusion criteria consisted of peer-reviewed articles written in English or Indonesian that discussed the implementation of Tadabbur Alam, Biomimicry, or STEAM in the context of science or educational learning, and that addressed spirituality, sustainability, or creativity.

Non-academic articles, opinion papers, technical reports, and publications lacking clear conceptual data were excluded. Two reviewers independently screened all titles, abstracts, and full texts. Inter-rater reliability was assessed using Cohen's kappa, which showed substantial agreement ($\kappa = 0.81$). Discrepancies were resolved through discussion.

From approximately 387 articles identified, a step-by-step selection process was conducted following the PRISMA 2020 guidelines, starting from title and abstract screening, duplication checks, and eligibility assessment, to full-text review. This sequential filtering process resulted in 63 articles meeting all inclusion criteria and being retained for synthesis**.** The article selection procedure is illustrated in the PRISMA flow diagram in Figure 1.

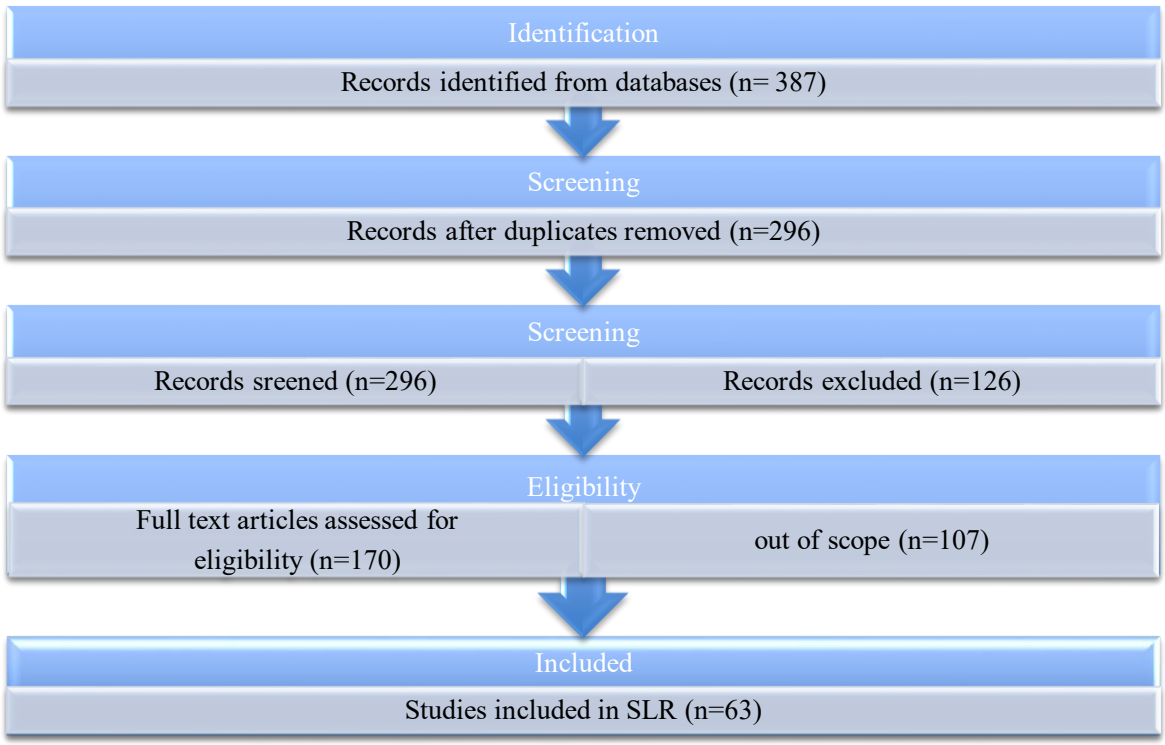


Figure 1. Article Selection Ssing the PRISMA Diagram

A quality appraisal was carried out using the Critical Appraisal Skills Programme (CASP) checklist to ensure the methodological rigor of the included studies. CASP was selected because it provides clear criteria for evaluating research validity, relevance, and potential sources of bias across qualitative and quantitative research designs. Only studies that met the minimum CASP quality thresholds were included in the final synthesis.

Data extraction covered essential information such as author, publication year, research design, learning approach, targeted outcomes, and key findings. A thematic analysis approach was employed to identify recurring patterns across studies. Initial codes were generated inductively, refined through constant comparison, and organized into higher-order themes that reflected conceptual consistencies in the literature. All steps of the review followed the PRISMA 2020 recommendations to ensure transparency and replicability.

Result and Discussion

Implementation and outcomes of Tadabbur Alam, Biomimicry, and STEAM-based learning

To clarify the theoretical foundation for synthesizing the TABS learning model, Table 1 presents the ten most relevant studies identified through the SLR.

Table 1. Summary of the Ten Most Relevant Studies Identified Through the SLR

No	Researcher & Year	Research Focus	Key Findings	Relevance to the TABS Model
1	Inayah (2018)	The influence of *Tadabbur Alam* activities on students' spiritual intelligence	A significant positive relationship was found between *Tadabbur Alam* and the improvement of students' spiritual intelligence.	Strengthens the reflective–spiritual dimension in building SusNess, particularly through direct experience with nature.
2	Desanda, (2025)	Implementation of the *Tadabbur Alam* model to foster environmental care character	Nature-based learning increases students' environmental concern, cooperation, and creativity.	Supports the development of SusNess through habituation of real actions and contextual learning.
3	Reswari et al., (2025)	*Tadabbur Alam* to cultivate environmental care character and its contribution to the SDGs	*Tadabbur Alam* activities foster social responsibility and environmentally friendly habits, such as planting and maintaining cleanliness.	Shows the potential of *Tadabbur Alam* in developing SusNess and ecological character from an early age.
4	L. L. Stevens et al. (2022)	Understanding and application of Life's Principles (LPs) in sustainable biomimicry design	95% of students understood LPs and were able to apply them in sustainable design; the main challenge was finding relevant biological analogies.	Relevant to the Biomimicry (Reflective Learning) dimension in TABS; connects observing nature (tadabbur) with creating sustainable innovative solutions.
5	(L. Stevens et al. (2019)	Design-based learning approach for functional biomimicry	Students understood the concept of "Nature as Model, Measure, and Mentor" and assessed sustainability based on Life's Principles.	Strengthens the integration of Biomimicry in TABS as a systemic and innovative thinking approach.
6	Hameed et al., (2022)	Biomimicry Design Spiral: Nature as a Model — a sustainable design model based on biological principles	The Biomimicry Design Spiral produces efficient and environmentally friendly designs; case studies include the Shinkansen train (kingfisher beak) and the Eastgate Center (termite mound).	Relevant to the Biomimicry (Action) dimension in TABS; emphasizes the application of nature-based principles in real technical systems and reinforces CREPs.
7	Pauls, (2017)	The role of biomimicry as a bridge between disciplines in STEAM education	Biomimicry increases student interest and creativity in linking scientific concepts with real applications, such as Velcro and the Shinkansen structure.	Relevant to the Biomimicry, STEAM integration in TABS for developing project-based, interdisciplinary CREPs.
8	Mejía-Villa et al., (2023)	Developing biomimicry training to improve CREPs and sustainability mindset	Biomimicry training improves the ability to find environmentally friendly solutions, systemic thinking, creativity, and sustainability orientation. Participants showed a significant increase in	Highly relevant: becomes the basis of stage B (Biomimicry) & S (STEAM Creative Problem-Solving) in the TABS model. Reinforces systems thinking, creativity, and sustainable design.

No	Researcher & Year	Research Focus	Key Findings	Relevance to the TABS Model
			sustainability problem-solving indicators.	
9	Bilen et al. (2020)	Development of biomimicry STEM activities based on organism structure–function	Students understood the relationship between organism structure and function and applied it to simple design solutions.	Shows that biomimicry effectively enhances systemic thinking and CREPs at the basic level.
10	Yeler (2015)	Creating Nature Awareness in Design Education	The "Nature & Design" project increased nature awareness; 96% of students realized the importance of nature's principles in design.	Relevant to the Tadabbur & Reflection dimension in TABS, strengthening the relationship between scientific knowledge and ecological awareness.

Table 1 shows that learning activities integrating direct observation of nature, spiritual value reflection, and creative exploration through science and design are effective in fostering two essential 21st-century student competencies: SusNess and CREPs. Desanda (2025, Inayah (2018), Reswari et al. (2025) emphasize that well-structured *Tadabbur Alam* activities can cultivate ecological empathy, social responsibility, and a strong commitment to maintaining environmental balance through direct experience and spiritual reflection on natural phenomena. Nature-based learning also strengthens students' affective dimensions, nurtures love for the environment, and guides their behavior toward sustainable living practices.

Furthermore, findings from L. L. Stevens et al. (2022) and (L. Stevens et al. 2019) indicate that applying Life's Principles and the concept of "Nature as Model, Measure, and Mentor" in biomimicry-based learning helps students develop systems thinking skills and a deeper ecological awareness. Hameed et al., (2022) further reinforce this by demonstrating that the Biomimicry Design Spiral effectively teaches students how to translate biological strategies into efficient and eco-friendly technical solutions, such as the Shinkansen train innovation and the Eastgate Center ventilation system. These findings confirm that biomimicry not only fosters scientific innovation but also instills sustainability values through the understanding of nature's principles.

From the perspective of creative thinking skills development, studies by Mejía-Villa et al., (2023) and Bilen et al. (2020) show that integrating biomimicry with STEM/STEAM to enhance CREPs significantly improves students' divergent, ideational, and reflective thinking abilities in formulating innovative solutions to real-world problems. Pauls, (2017) supports this finding, emphasizing that biomimicry serves as a cross-disciplinary bridge in STEAM education connecting scientific theory with real-world applications while strengthening students' collaborative and creative skills. Furthermore, Yeler (2015) adds that Nature & Design-based learning can heighten students' awareness of ecological and aesthetic values in sustainable design practices.

Overall, the results of this SLR indicate that the integration of Tadabbur Alam, Biomimicry, and STEAM has a strong empirical and conceptual foundation for developing SusNess and CREPs. Collectively, the reviewed studies demonstrate that each approach contributes a distinct but complementary mechanism for cultivating 21st-century competencies. Tadabbur Alam

fosters moral and spiritual foundations as the basis for ecological awareness; Biomimicry transforms reflective values into sustainable scientific innovation; and STEAM provides a collaborative and interdisciplinary framework to translate ideas into creative, applicable solutions.

These convergent findings reinforce the theoretical argument of the current study: when combined, the three approaches generate a continuous learning pipeline from awareness, to understanding, to creative application that simultaneously engages cognitive, affective, and psychomotor domains. This explains why the TABS model is theoretically robust: it synthesizes mechanisms that are empirically proven to enhance ecological literacy, creativity, problem-solving, and interdisciplinary collaboration. Thus, integrating the three approaches within the TABS model offers a holistic and evidence-based framework capable of developing learners who are creative, reflective, and committed to environmental and social sustainability.

The Conceptual Relationship among Tadabbur Alam, Biomimicry, and STEAM in Developing SusNess and CREPs

Thematic analysis of the Systematic Literature Review reveals that *Tadabbur Alam*, Biomimicry, and STEAM play complementary roles in developing two key 21st-century student competencies, SusNess and CREPs. *Tadabbur Alam* plays a vital role in fostering SusNess through spiritual, reflective, and emotional experiences with nature. This process strengthens the human nature God relationship through contemplative activities that cultivate ecological and moral responsibility (Desanda, 2025; Inayah, 2018; Muzzammil et al., 2024; Reswari et al., 2025). Through direct observation and reflection in nature, students learn to recognize the order within God's creation and understand the impact of human behavior on environmental balance (Islam et al., 2025). Such activities nurture three dimensions of SusNess as outlined by Kurnia et al. (2020) that sustainability practice awareness, the application of eco-friendly habits in daily life; behavioral and attitude awareness, the formation of positive environmental attitudes and behaviors; and emotional awareness, emotional sensitivity to surrounding ecological conditions.

Biomimicry, on the other hand, serves as a bridge between ecological reflection and scientific innovation. Through the principle of *"nature as model, measure, and mentor,"* students learn to emulate the adaptive strategies of organisms to create efficient and sustainable solutions (Hameed et al., 2022; L. Stevens et al., 2019). Studi L. L. ; Stevens et al. (2022) confirms that biomimicry-based learning enhances students' systems thinking and awareness of nature's Life's Principles. Similarly, Mejía-Villa et al., (2023) demonstrate that integrating biomimicry in developing CREPs effectively improves participants' divergent thinking skills and sustainability awareness. Thus, biomimicry becomes central to CREPs development by training students to think creatively, reflectively, and adaptively when solving real-world, context-based problems.

Meanwhile, the STEAM approach provides a methodological framework that enables the synergy of the previous two approaches through collaborative and contextual learning activities. By integrating science, technology, engineering, arts, and mathematics, students are encouraged to express scientific ideas in the form of creative and applicable works (Pauls, 2017). The STEAM approach also contributes to the enhancement of CREPs by combining divergent thinking (generating multiple innovative ideas) and convergent thinking (selecting the most

effective solutions) (Bilen et al., 2020). Through such interdisciplinary project-based learning, students not only develop scientific reasoning but also learn to make decisions that consider the social and ecological impacts of every innovation they create (Yeler, 2015).

Thus, the integration of *Tadabbur Alam*, Biomimicry, and STEAM forms a synergistic conceptual relationship: *Tadabbur Alam* provides the spiritual and empathetic foundation toward nature; Biomimicry translates reflective values into scientific and ecological innovation; and STEAM serves as a collaborative platform that enables students to develop SusNess and CREPs in a balanced manner. Together, these three approaches establish a holistic learning framework that cultivates not only intellectual intelligence but also ecological character and moral responsibility among students toward the sustainability of life on Earth.

Conceptual Synthesis Leading to the Design of the TABS (TABS) Learning Model

The learning stages of the TABS model were developed through a process of conceptual and empirical synthesis based on the results of a SLR of 63 relevant articles encompassing the three core approaches: *Tadabbur Alam*, Biomimicry, and STEAM. This synthesis involved identifying recurring patterns of activities, pedagogical principles, and learning outcomes reported across studies, then integrating these elements into a systematic, reflective, and applicable learning sequence. Conceptually, the eight-stage structure of the TABS model is inspired by:

1. The reflective–spiritual stages of *Tadabbur Alam,* which emphasize observation, contemplation, and the internalization of meaning from natural phenomena (Alandika, 2022; Inayah, 2018; Muzzammil et al., 2024). These elements form the foundation for the observation reflection idea distillation phases.
2. The Biomimicry Design Spiral model (Biomimicry institute, 2017; Hameed et al., 2022; Rossin, 2010), which includes the stages of identify, translate, discover, emulate, evaluate, and refine. This model serves as the basis for developing the translate, discover, emulate, evaluate phases in TABS. The spiral approach ensures that learning occurs in an iterative, solution-oriented manner.
3. The pedagogical principles of STEAM Project-Based (Alves et al., 2019; Cortes et al., 2024; Diego-Mantecon et al., 2021*)* which emphasize the integration of science, technology, art, and creative design within real-world project contexts. These principles underpin the stages of project implementation, interdisciplinary collaboration, and result dissemination in the TABS model.

Methodologically, the TABS model was developed by integrating reflective stages (from *Tadabbur Alam*), innovative stages (from Biomimicry), and collaborative stages (from STEAM) into a logical sequence of scientific and creative learning. This integration resulted in the formulation of the TABS learning model syntax, consisting of the following stages: stimulus and problem triggering, observation and reflection (*Tadabbur Alam*), distill (idea refinement), translate (translating ideas into solutions), discover (identifying natural models), emulate (replicating and developing STEAM-based products), evaluate (assessing designs and products), and presentation and final reflection. The detailed syntax of the TABS learning model is presented in Table 2.

Table 2. Syntax of the Implementation of the TABS Learning Model

No.	Learning Stage	Description of Activities	Example of Implementation	Pedagogical Objectives / Rationale
1	Stimulus and Problem Elicitation	The lecturer provides an introductory explanation and presents a cognitive conflict to encourage students to think critically and recognize real-world problems that require solutions.	The lecturer presents various real environmental issues (e.g., pollution, climate change, energy crisis, or household waste) and asks students to select and identify the root problem they wish to investigate.	1. Develop SusNess (behavioral awareness): critical awareness of sustainability issues. 2. Strengthen CREPs (problem identification): the ability to recognize and define problems scientifically and meaningfully.
2	Observation and Reflection (*Tadabbur Alam*)	Students observe natural phenomena, reflect on their findings, draw moral and ecological insights, and develop an attitude of sustainability.	Students conduct field observations around campus or in a garden, record the process of organic decomposition by fungi, and write a reflection on "What can we learn from the role of fungi in maintaining ecological balance?"	1. Enhance SusNess (emotional awareness) through reflective experience and spiritual ecological consciousness. 2. Strengthen CREPs (information gathering): the ability to observe and collect meaningful data from real phenomena.
3	Distill (Filtering Design Ideas)	Students clearly define the problem, determine the main design function, constraints, and objectives.	Students formulate an idea: "How can we imitate the way fungi decompose organic matter to create an efficient and sustainable composting system?"	1. Cultivate SusNess (practice awareness): understanding the human role in maintaining ecological balance. 2. Enhance CREPs (problem clarification & idea definition): the ability to analyze and synthesize reflective ideas.
4	Translate (Translating Solution Ideas)	Students transform inspiration from nature into design concepts by studying relevant biological principles.	Students study the structure of fungal hyphae and enzymes involved in decomposition, then design several eco-composter concepts that mimic fungal systems.	1. Strengthen SusNess (cognitive understanding): rational understanding of natural efficiency and harmony. 2. Develop CREPs – idea generation (divergent thinking): the ability to generate multiple innovative solutions based on natural sustainability principles.
5	Discover (Identifying Natural Models)	Students search for and analyze natural models that can serve as references or prototypes for solutions.	Students examine various species of decomposer fungi and identify the most efficient one as a basis for their bio-decomposer design.	1. Improve CREPs (idea analysis) (convergent thinking): the ability to analyze and select the most effective ideas. 2. Foster SusNess (systems thinking): understanding interconnections within ecosystems.
6	Emulate (Imitating and Developing STEAM Products)	Students imitate natural principles to design innovative STEAM-based products integrating science, technology,	Students design a fungal-inspired eco-composter incorporating temperature sensors (technology), air circulation systems (engineering), and aesthetic	1. Reinforce SusNess (practice awareness) through concrete sustainable action. 2. Strengthen CREPs (implementation & innovation): through

		engineering, art, and mathematics.	design (art) using recycled materials.	interdisciplinary collaboration and real-world application of ideas.
7	Evaluate (Evaluating Design and Product)	Students test and simulate the technical function and sustainability value of their product.	Students test the composting device over two weeks, assessing efficiency, temperature stability, and environmental sustainability.	1. Enhance CREPs (evaluation & reflection): the ability to critically assess the effectiveness of solutions. 2. Develop SusNess (practice awareness): considering social and ecological impacts of innovations.
8	Presentation and Final Reflection	Students present their designs, process reflections, and sustainability values through scientific posters in a class symposium that also facilitates feedback and idea exchange among groups.	Students present a poster titled *"Learning Sustainability from Fungi: An Inspiration for Eco-Friendly Waste Management."*	1. Cultivate SusNess (emotional awareness): internalization of moral values, ecological empathy, and social responsibility. 2. Integrate CREPs – communication & metacognitive reflection: the ability to communicate scientific ideas and reflect on cognitive processes.

Overall, the eight stages can be flexibly adapted across various science courses, whether project-based, research-oriented, or field-based learning. These stages in the TABS model demonstrate a continuous progression linking spiritual reflection (*Tadabbur Alam*), scientific and creative exploration (Biomimicry), and collaborative application (STEAM). This synthesis aligns with the perspective of (Horn et al., 2024), who state that transdisciplinary learning effectively integrates knowledge, values, and actions into a holistic process. Consequently, the TABS model serves as a pedagogical strategy to develop students who are not only competent problem solvers but also conscious sustainability agents who act ethically and are committed to sustainable living.

Beyond the thematic findings, it is also important to highlight the methodological robustness of this review to ensure that the conclusions drawn from the synthesized literature are credible and trustworthy. A key methodological strength of this review is the incorporation of inter-rater reliability assessment during the screening process. Cohen's kappa coefficient was used to evaluate the level of agreement between the two independent reviewers, resulting in substantial agreement ($\kappa = 0.81$). This strengthens the credibility of the review by demonstrating that article selection was carried out consistently and objectively. The reliability check also minimizes the risk of reviewer bias, a common challenge in systematic reviews of educational research. Despite this strength, the interpretation of methodological quality still depends on the subjective judgment of reviewers to some extent, although the reliability procedures significantly reduced its impact.

Contribution of the TABS Model to the Development of SusNess and CREPs

The TABS model contributes to science learning through two interrelated and continuous dimensions. The first is the SusNess dimension, which cultivates students' sense of care, moral responsibility, and concrete actions toward environmental issues through reflective experiences and nature-based contextual learning (Inayah, 2018). *Tadabbur Alam* activities encourage

students to understand the relationship between humans and nature from both spiritual and ecological perspectives, fostering environmentally conscious and sustainable (Desanda, 2025).

Second, the CREPs dimension plays a role in developing students' critical, divergent, and innovative thinking abilities in formulating solutions to real-world problems based on principles of natural sustainability (Treffinger & Isaksen, 2013).. Through the biomimicry and STEAM project stages, students are trained to analyze natural systems, emulate the adaptive strategies of organisms, and transform them into creative and applicable scientific solutions (Pathak, 2019; Topaz, 2016; Zari, 2015).

These two dimensions do not operate linearly but interact dynamically in a spiral learning cycle that continuously connects and reinforces the cognitive, affective, and psychomotor domains (Sadat et al., 2022). When students engage in *Tadabbur Alam*, they develop ecological empathy and reflective awareness (Nahdiyah et al., 2023); during the biomimicry stage, they internalize principles of sustainability and systems thinking (Collado-Ruano, 2018; Vázquez-Villegas et al., 2024); and through STEAM activities, they translate these values into collaborative action and tangible innovation (Gulhan, 2023; Resi et al., 2020). Because each stage builds upon and loops back to the previous one, students continuously refine their creativity, ecological literacy, and reflective capacity through repeated cycles of observation, interpretation, design, and evaluation. This integrative process creates a balance between scientific knowledge, ecological awareness, and applied creativity, positioning TABS as a holistic learning model capable of producing graduates who think critically, act ethically, and are committed to the sustainability of life.

Overall, the results of this systematic review confirm that the integration of *Tadabbur Alam*, Biomimicry, and STEAM provides a strong empirical and conceptual foundation for developing a learning model that enhances students' SusNess and CREPs. The TABS model can serve as a strategic alternative for higher education institutions to implement the principles of ESD in a contextual and spiritual manner, aligning with the *Merdeka Belajar–Kampus Merdeka* initiative.

Conclusion

This SLR was conducted to formulate an integrative learning model based on Tadabbur Alam, Biomimicry, and STEAM (TABS) by addressing three research questions related to implementation, conceptual relationships, and model synthesis. The findings clearly demonstrate that the integration of these approaches has a strong conceptual and empirical foundation for advancing science education in higher education.

First, in relation to the first research question, the review confirms that the implementation of Tadabbur Alam, Biomimicry, and STEAM has consistently contributed to improving holistic learning outcomes. Tadabbur Alam develops spiritual awareness and ecological empathy through reflective engagement with nature. Biomimicry enhances systems thinking and sustainable innovation by translating biological strategies into design ideas. STEAM strengthens creativity, collaboration, and the contextual applicability of scientific concepts through interdisciplinary project-based learning.

Second, answering the second research question, the conceptual relationship among these approaches forms a synergistic framework for developing students' SusNess and CREPs two

core 21st-century competencies. Tadabbur Alam provides a moral and value-based foundation for ecological consciousness; Biomimicry bridges reflective awareness with sustainable problem-solving; and STEAM offers a methodological pathway for transforming ideas into creative, implementable solutions.

Third, in response to the third research question, this synthesis results in the TABS learning model an operational, contextual, and spiral framework consisting of eight interconnected stages: problem elicitation, reflection (tadabbur), idea distillation, solution translation, exploration of natural models, emulation, evaluation, and final reflection. Through this structure, TABS cultivates SusNess via reflective–spiritual engagement and enhances CREPs through biomimicry–STEAM project implementation.

Overall, the study highlights the novelty of the TABS model as a holistic, transdisciplinary learning framework that uniquely bridges spirituality, ecological understanding, and creative scientific problem-solving. By combining reflective, scientific, and design-based learning processes, the TABS model offers a powerful alternative for higher education institutions seeking to implement Education for Sustainable Development in a manner that is meaningful, innovative, and aligned with 21st-century competencies.

Credit Authorship Contribution Statement

Sulasfiana Alfi Raida: Conceptualization, Methodology, Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Saiful Ridlo:** Conceptualization, Methodology, Supervision, Validation. **Hartono:** Methodology, Resources, Supervision, Project administration. **Aditya Marianti:** Validation, supervision, funding acquisition, Project administration.

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