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ORIGINAL

Integration of Design Thinking and Naik Dango Local Wisdom: A New Paradigm for Enhancing 4C Skills in Biology Learning

Integración del Pensamiento de Diseño y la Sabiduría Local Naik Dango: Un Nuevo Paradigma para Mejorar las Habilidades 4C en el Aprendizaje de la Biología

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ABSTRACT

This study aims to develop a learning model based on the local wisdom of Naik Dango integrated with design thinking to empower students' 4C skills (critical thinking, creativity, communication, and collaboration). These skills are essential in 21st-century education, while the introduction and preservation of local wisdom are important to maintain cultural diversity. Therefore, this study focuses on developing a learning model that can introduce and preserve local culture while enhancing students' 21st-century skills. The research employed a Research and Development (R&D) approach by Plomp and Nieveen, consisting of three stages: (1) preliminary research, (2) prototyping phase, and (3) assessment phase. Data were collected through expert validation, observation, and questionnaires to assess the model's practicality and effectiveness, and then analyzed using ANCOVA to examine differences in learning outcomes and students' 4C skills. The validity test results indicated that all learning materials were valid, with substantial to perfect reliability. The practicality evaluation showed that the Naik Dango learning model integrated with design thinking was very well received by students, with an average positive response rate of 87,20 %. The effectiveness test demonstrated a significant improvement in students' 4C skills after using this model ($p < 0,05$). In conclusion, the Naik Dango learning model integrated with design thinking proved to be an effective, relevant, and contextual learning strategy, which not only enhances students' 4C skills but also introduces and preserves local cultural values. This model can serve as an innovative alternative for culture-based biology education and 21st-century learning.

Keywords: Learning Model; Local Wisdom; Naik Dango; Design Thinking; 4C Skills.

RESUMEN

Este estudio tiene como objetivo desarrollar un modelo de aprendizaje basado en la sabiduría local de Naik Dango integrado con design thinking para potenciar las habilidades 4C de los estudiantes (pensamiento crítico, pensamiento creativo, comunicación y colaboración). La educación del siglo XXI requiere estas habilidades, mientras que la introducción y preservación de la sabiduría local es importante para mantener la diversidad cultural. Por lo tanto, este estudio se centra en el desarrollo de un modelo de aprendizaje que pueda introducir y preservar la cultura local al mismo tiempo que mejora las habilidades del siglo XXI de los estudiantes. El estudio utiliza un enfoque de Investigación y Desarrollo de Plomp y Nieveen con tres etapas: (1) investigación preliminar, (2) fase de prototipado y (3) fase de evaluación. Los datos se recopilaron a

través de la validación de expertos, observaciones y cuestionarios para evaluar la practicidad y efectividad del modelo, y luego se analizaron mediante análisis ANCOVA para examinar las diferencias en los resultados de aprendizaje y las habilidades 4C de los estudiantes. Los resultados de la prueba de validez mostraron que todos los materiales de aprendizaje son válidos, con una fiabilidad de sustancial a perfecta. La evaluación de la practicidad mostró que el modelo de aprendizaje Naik Dango integrado con design thinking fue muy bien recibido por los estudiantes, con un porcentaje promedio de respuestas positivas del 87,20 %. La prueba de efectividad mostró un aumento significativo en las habilidades 4C de los estudiantes después de usar este modelo ($p < 0,05$). En conclusión, el modelo de aprendizaje Naik Dango integrado con design thinking se ha demostrado como una estrategia educativa efectiva, relevante y contextual, que no solo mejora las habilidades 4C de los estudiantes, sino que también introduce y preserva los valores culturales locales. Este modelo puede considerarse una alternativa innovadora en la educación de biología basada en la cultura y en la enseñanza del siglo XXI.

Palabras clave: Modelo de Aprendizaje; Sabiduría Local; Naik Dango; Design Thinking; Habilidades 4C.

INTRODUCTION

Mastery of skills has become a necessity in 21st-century education to face increasingly complex global challenges, especially in a world that is advancing through technological progress and globalization. Critical thinking, creative thinking, collaboration, and communication (4C) skills are key factors in developing students' abilities.[1,2] The topic of environmental pollution, in general, is often considered complex and difficult for students to understand, given the various types of pollutants and their impacts on ecosystems, as well as the many concepts that require deep understanding. For example, studying environmental pollution requires understanding the types of pollutants, the processes of their spread in the environment, and the interactions between pollutants and ecosystem components such as air, water, and soil. Therefore, to help students comprehend this topic, deep critical and creative thinking skills are necessary, which can be developed through an appropriate and structured learning approach. Education that focuses on developing 4C skills is crucial, especially at the secondary education level, which serves as the foundation for students to develop their potential in this modern era.

The concept of 4C skills (critical thinking, creative thinking, collaboration, and communication) began to develop in the 21st century alongside technological advancements and globalization, which require education to prepare students for future challenges. This concept was first introduced in 21st-century education in the early 2000s as a response to global changes that demand broader skills from students. Along with this development, local wisdom such as Naik Dango emerged as a relevant approach to introduce local culture while supporting context-based learning. The Naik Dango tradition embodies values of togetherness, collaboration, respect for nature, appreciation of ancestral heritage, and willingness to sacrifice, which can support the development of 4C skills as well as reflective thinking about the relationship between humans, the environment, and society.[3,4,5] The integration of local wisdom in education, particularly in science and environmental learning, can also foster ecological awareness, social responsibility, and students' ability to apply knowledge contextually.[6,7]

In addition to local wisdom, the Design Thinking approach is relevant for the development of 4C skills. Design Thinking is a learning method that emphasizes creative and collaborative problem-solving through five stages: Empathize, Define, Ideate, Prototype, and Test.[8,9] This approach encourages students to think analytically, creatively, and to collaborate in teams, making it highly relevant for developing 4C skills and students' digital literacy. Design Thinking has also been integrated with popular learning models such as STEAM, STEM, and PjBL-STEM, demonstrating its potential to enhance creativity and problem-solving abilities.[10,11]

Based on this background, this study aims to develop a learning model that integrates the local wisdom of Naik Dango with Design Thinking to preserve cultural values while empowering students' 4C skills. This learning model was developed based on previous studies demonstrating the effectiveness of applying Design Thinking to enhance students' creativity and problem-solving abilities,[12] as well as integrating local wisdom to strengthen student engagement and the relevance of learning materials to their cultural context.[13]

This integration provides new insights for the educational literature, particularly in the context of culture-based Biology learning, and offers a learning paradigm that is adaptive, contextual, and responsive to the demands of 21st-century competency-based education. Some of the articles analyzed to support this study can be seen in (table 1).

Tabel 1. Research Gap Analysis from Several Articles

Article Title	Gap Research	Methodology Research	Limitations	Findings
Education Based on Local Wisdom: An Alternative Model for the Integration of Cultural Values in the School Curriculum In Indonesia.[14]	The limited application of local wisdom in the curriculum that focuses on practical aspects within a specific cultural context	Literature review and case study in 5 schools	Difficulty in designing a curriculum that is relevant to the diverse local cultures in Indonesia	Integration of local wisdom can enrich learning with a contextual and relevant approach
Integrating Local Wisdom and Modern Education: A Holistic Approach to Curriculum Development.[15]	The limitation of research that studies the direct impact of integrating local wisdom on the achievement of SDGs in education.	Survey of 10 schools that implement local wisdom in the curriculum	Disparities in the implementation and measurement of its impact on the achievement of SDGs	Learning based on local wisdom can increase environmental and social awareness, as well as foster a sense of ownership of local culture
Combining Indigenous Knowledge and Modern Education to Foster Sustainability Competencies: Towards a Set of Learning Design Principles.[16]	Limited understanding of the relevance of traditional knowledge in the context of modern, digitally-driven education	In-depth interviews with teachers and education practitioners who use local knowledge	Cultural barriers and resistance from the education community that focuses more on international approaches	Traditional knowledge, when accepted and taught contextually, can enrich the learning experience and develop students' critical thinking skills
Integration of indigenous and local knowledge into sustainability education: a systematic literature review.[17]	Gap in developing a systematic framework to integrate local wisdom with the goals of sustainable education	Development of a framework and experiments with a community-based approach	Limitations in quantitative data regarding the effectiveness of local knowledge-based teaching	Education based on local wisdom can contribute to achieving sustainable education by introducing relevant ecological and social concepts
Community Development in the Rural Areas through Traditional Indigenous Knowledge.[18]	Lack of studies assessing innovative ways to integrate traditional knowledge into formal and informal learning	Case study in rural communities with local community participation	Differences in the level of community readiness to accept the integration of traditional knowledge into the education system	Traditional knowledge enriches students' life skills and supports more applicable contextual learning
A Systematic Review on Design Thinking Integrated Learning in K-12 Education.[19]	Limited empirical evidence supporting the effectiveness of integrating Design Thinking in K-12 education	A systematic review of 43 SSCI articles	The study focuses more on the STEM curriculum and less on specific local or cultural contexts	Design Thinking shows great potential in K-12 education, but empirical evidence is still limited
The Effectiveness of Design Thinking in Improving Student Creativity Skills and Entrepreneurial Alertness.[20]	The limited research examining the impact of Design Thinking on creativity and entrepreneurship	Quasi-experiment with two groups of students	Limitations in generalizing results due to the small sample size	Design Thinking can enhance students' creativity and entrepreneurship skills
Design Thinking as an Active Teaching Methodology in Higher Education: a Systematic Review.[12]	Limited understanding of the application of Design Thinking as an active teaching methodology in higher education	Documentary research on 28 studies	Variations in the application and understanding of the Design Thinking concept	Design Thinking is effective in enhancing the learning experience through active participation and collaboration
Learning Design Thinking Through a Hands-On Learning Model.[21]	Limitations of case studies implementing a practice-based learning model in teaching Design Thinking	Case study with a practice-based learning approach	Challenges in adapting the learning model to various contexts	Practice-based learning is effective in teaching the principles of Design Thinking
Design Thinking in Action: A Quantitative Study of Design Thinking Practices in Innovation Projects.[22]	Limited understanding of the variation in Design Thinking practices in innovation projects based on goals and levels of uncertainty.	Survey of 221 Design Thinking-based innovation projects	Complexity in measuring and comparing practices across different projects	Design Thinking practices vary depending on the project's goals and levels of uncertainty

METHOD

This research uses a Research and Development (R&D) Plomp & Nieveen approach,[23] aimed at developing a learning model based on the local wisdom of Naik Dango integrated with design thinking, as well as determining the practicality and effectiveness of the model. This study is non-observational, as it focuses on the development and testing of the learning model prototype, rather than just observing existing phenomena in the field.

The research was conducted in Ngabang City, West Kalimantan Province, which is predominantly inhabited by the Dayak Kanayatn ethnic group. The population for this study consists of junior high school students in the area. The sample used in this research consisted of 85 students, selected randomly from several participating schools.

This study involves several key variables, including the independent variable, the Naik Dango learning model integrated with design thinking, and the dependent variable, students' 4C skills, which include critical thinking, creative thinking, communication, and collaboration. Data collection was conducted in several phases. The preliminary research phase involved a needs analysis to understand the learning needs in the schools involved, adjusted to the local cultural context. The prototyping phase involved the development of the Naik Dango learning model prototype integrated with design thinking. This prototype was then validated by subject matter experts, learning experts, and learning evaluation experts to ensure its quality and relevance. The assessment phase included data collection through observations of the implementation of the learning process, where the implementation of the learning model was observed to see its effectiveness in improving students' 4C skills. Additionally, student response questionnaires were used to gather feedback on the practicality and satisfaction of students with the implemented learning model. Furthermore, effectiveness testing was carried out through a quasi-experimental design using a Non-equivalent Pretest-Posttest Control Group Design, involving an experimental group and a control group,[24] as shown in table 2.

This study has received ethical approval from the relevant authority. All participants in the study were provided with clear information about the purpose of the research, and they gave voluntary consent to participate. In addition, the participants' identities were kept confidential, and all data collected was used solely for the purposes of this research. The instruments used in this study included a model validation questionnaire, to assess the quality and suitability of the developed learning model; a learning tools validation rubric, to assess the effectiveness of the learning tools used; implementation observation sheets, to record the application of the learning model in the teaching process; student response questionnaires, to measure students' acceptance of the learning model; and a 4C skills test, which measures students' critical thinking, creative thinking, communication, and collaboration.

Table 2. Quasi-Experimental Research Design

Group	Pretest	Treatment	Posttest
A1	O1	X1	O2
A2	O3	X2	O4

Source: Cohen et al.[24]

Description:
A1: experimental group with the Naik Dango model.
A2: control group with the creative Problem Solving model.
X1: class with the Naik Dango learning model integrated with design thinking.
X2: class with the Creative Problem Solving learning model.
O1, O3: pretest of 4C skills.
O2, O4: posttest of 4C skills.

RESULTS

In this study, we developed and designed a prototype of a learning model based on the local wisdom of Naik Dango integrated with design thinking to empower students' 4C skills. This model was designed with the aim of creating more structured and relevant learning, as well as helping students to be more effective in solving real-world problems through the skills they possess.

Table 3 illustrates the integration of the Naik Dango cultural values into the development of a learning model designed to foster essential 21st-century competencies, particularly critical thinking, creativity, communication, and collaboration. Each cultural principle Barage (collective solidarity), Karajasama (mutual cooperation), Namu Ide (idea generation), Marancang (prototype design), and Uji (prototype testing) is organized with established educational theories, such as constructivism, project-based learning, and collaborative learning frameworks.

Table 3. Integration of Naik Dango Local Wisdom and Design Thinking in Learning Model Development

Cultures Value	Value Description	Design Thinking	Learning Syntax	Theoritical Support
Togetherness	Togetherness aims to maintain the community in a harmonious and cooperative state, creating an atmosphere of peace and unity.	Empathize: The value of togetherness, which prioritizes cooperation and mutual assistance, is highly relevant to this phase, where students must empathize and understand the needs of others, both emotionally and physically.	Barage: Barage is a local term from the Dayak Kanayatn language that means togetherness. At this stage, the teacher gathers students into groups and then conducts an ice-breaking activity, preferably using the local language, to motivate and encourage students to work collaboratively, supporting each other in solving problems.	Piaget emphasized the importance of students' active experiences in constructing understanding, which aligns with the development of empathy in understanding other people's situations.[25] Learning through observation and social interaction enhances the ability to empathize and cooperate within the group.[26] Deep social interaction can enhance understanding of other people's problems.[27] Cooperation among students to enhance understanding through group discussions supports empathetic learning.[28] Bruner stated that empathy in social learning builds knowledge contextually, including in social problem-solving.[29]
Cooperation	Mutual assistance in traditional ceremonies and social life, putting oneself in another person's situation, and feeling what others feel.	Define: The value of cooperation is related to the define phase, where understanding the challenges faced needs to be clearly articulated. Cooperation emphasizes the importance of solidarity in dealing with shared problems.	Karajasama: Karajasama is a local term from the Dayak Kanayatn language that means cooperation. At this stage, students read a passage related to environmental pollution, then learn to recognize their roles within the group and adjust themselves to other members in carrying out problem-solving activities.	Helping students define problems and challenges based on their social experiences and prior knowledge.[30] Polya taught concrete steps in defining problems and finding effective solutions.[31] Learning that focuses on deep experiences defines problems based on real contexts and prior experiences.[32] Helping students plan and define problems independently, enhancing self-regulation in learning.[33] The development of critical thinking skills is essential in defining and understanding problems through logical reasoning.[34]
Relationship with Nature	Appreciating nature as a part of life, practicing farming in ways that respect the environment and natural balance.	Ideate: The value of relationship with nature is included in the ideate phase, where students are expected to create innovative solutions that also consider sustainability and environmental preservation, which are part of the Naik Dango local wisdom.	Namu Ide: Namu Ide is a local term from the Dayak Kanayatn language that means finding an idea. At this stage, each student is required to come up with one creative solution, and then they engage in discussions to identify the most appropriate and sustainable innovative solution, taking into account environmental aspects and nature conservation in the learning process.	Encouraging the development of creative ideas to solve problems with an innovative approach.[35] Encouraging students to think creatively and generate multiple solutions for complex problems.[36] Focusing on the development of creative ideas based on innovation-oriented teaching to address problems.[37] Producing creative solutions through group collaboration to address real-world problems.[38] Teaching students to think creatively in formulating ideas to solve real-life problems.[39]
Respect for ancestral heritage	Appreciating traditions and customs inherited from the ancestors, preserving the continuity and authenticity of the culture.	Prototype: Respect for ancestral heritage is applied in the prototype phase, where the prototype or solution must	Marancang: Marancang is a local term from the Dayak Kanayatn language that means designing. At this stage, students design or create a prototype of the	Using social interaction to design solutions that reflect local cultural values in the form of prototypes.[40] Project-based learning provides hands-on experience

		reflect the values inherited from the ancestors, such as preserving and maintaining traditions through concrete actions.	proposed solution, which is developed to reflect local cultural values, while preserving and maintaining ancestral heritage.	in developing prototypes that take cultural heritage into consideration.[41] Learning should be relevant to the social and cultural context and help students understand the importance of the local context in prototype development.[42] Learning through hands-on experience in creating prototypes while taking social and cultural contexts into account.[43] Knowledge is constructed based on direct experience and by integrating existing cultural values.[44]
Willingness to Sacrifice	Students are expected to be ready and willing to sacrifice for the welfare and common interests of the community or group.	Test: The willingness to sacrifice for the common good is highly relevant in the test phase, where the prototype results are tested and improved, with the readiness to make sacrifices for the benefit of the group or community.	Uji: Uji is a local term from the Dayak Kanayatn language that means testing. At this stage, students test and refine the results of their prototype to ensure that the solution produced serves the common good.	Teaching the importance of cooperation in testing prototypes and sharing feedback to improve solutions together.[45] Testing and revising prototypes based on evidence to refine solutions.[46] Using experiments to test ideas and improve them based on feedback results.[47] Constructive feedback is used to improve test results and create more effective solutions.[48 Learning from experience and social interaction to improve test results and refine the prototype.[26]

The distinct advantages of the Naik Dango syntax compared to other problem-solving models lie in: (1) the integration of local cultural values as the core of the syntax rather than merely as contextual elements; (2) the use of local language and symbols that strengthen students' identity; (3) a communal orientation that emphasizes solidarity, mutual cooperation, and sacrifice; (4) ecological awareness embedded in every stage of the solution; and (5) the spiritual dimension and ancestral heritage as the foundation for designing solutions. Thus, Naik Dango is not merely a model for problem-solving, but also a model of character and cultural education that is relevant to both local and global contexts.

After developing and designing a problem-based learning model that integrates the local wisdom of Naik Dango with Design Thinking, the next step is to translate these theories and concepts into forms that can be directly applied in the classroom. One approach is to design a Student Worksheet (LKPD) specifically for the topic of environmental pollution. This LKPD is structured to empower the 4C skills (critical thinking, creativity, collaboration, and communication). Through this worksheet, students are provided with opportunities to deepen their understanding of biological concepts related to environmental pollution while collaboratively working to solve problems relevant to their lives. Thus, the LKPD functions as a practical tool that bridges learning theories with classroom practice, while simultaneously optimizing students' competencies.

Table 4. Student Worksheet Based on the Naik Dango Learning Model Integrated with Design Thinking

STUDENT WORKSHEET
Topic: environmental pollution
Class: VIII Middle School
Learning Model: Naik Dango Integrated with Design Thinking
Basic Competence:
Analyzing the causes, types, impacts, and methods of mitigating environmental pollution.
Learning Objectives:
Training students' critical thinking skills in analyzing environmental pollution.
Developing students' creativity through ideas and solution designs/proposals.
Accustoming students to working collaboratively in groups.
Encouraging communication skills through the presentation of their work results.

Stage 1: *Barage* (Togetherness)
Ice Breaking (5 minutes): (dipandu menggunakan bahasa daerah)
The teacher invites students to play the game *"Environmental Word Chain"*:
The teacher begins by saying the word "Environment."
The first student must say a related word, for example, "Water."
The next student continues, for example, "River," "Trash," "Air," and so on.
Any student who runs out of words is given a light challenge (for example, mentioning three ways to protect the environment).
Teacher's Instructions:
Conduct the ice-breaking activity to build a sense of togetherness.
Divide students into groups of 4–5.
Discuss the question: *What types of pollution do you most often encounter in your daily life?*
Write the results of your discussion in the group's answer box.
4C Skills: Communication, Collaboration
Stage 2: *Karajasama* (Collaborating)
Reading the Passage:
Landak, West Kalimantan, mentarikhatulistiwa.co.id — The Head of Sungai Segak Village, Moh. Syarif, Sap., spoke out regarding illegal mining activities occurring in the upstream area of the Landak River. He regretted the actions of illegal miners who were deemed to have polluted the river ecosystem, damaged the environment, and threatened the source of clean water for residents. "Illegal mining conducted in the upstream of the Landak River has caused very serious pollution. This is not only about environmental damage, but it also directly impacts the lives of the community," said Moh. Syarif in his statement. According to him, uncontrolled mining activities may benefit certain groups but create huge losses for the wider community, especially those living along the Landak River. The river ecosystem is said to have suffered severe damage. Fish and other aquatic biota are threatened with death due to waste freely flowing into the river. "The river water that used to be clear and even drinkable during the dry season can no longer be used," he said. He emphasized that the Landak River is one of the main water sources for the village community. This pollution not only destroys the environment but also threatens the community's water and food security.
Group Formation and Role Distribution:
Form groups of 4–5 students.
Assign roles (can be rotated in the next meeting):
Moderator, responsible for maintaining the flow and managing time during the discussion.
Data Analyst, responsible for highlighting important points from the passage and conducting simple experiments.
Recorder, responsible for filling in tables and writing summaries.
Presenter, responsible for preparing a 1-minute oral report.
4C-Based Instructions: Critical Thinking Skills
Discuss with your group members: what are the negative impacts of illegal mining in the upstream Landak River on the environment, health, and community life?
Identify evidence from the passage or real facts you have seen that show pollution and ecosystem damage in the Landak River.
Compare the condition of the Landak River in the past (clear, drinkable) and the present (polluted). What is the main cause?
Stage 3: *Namu Ide* (Generating Ideas)
Individual Assignment:
Re-read the passage about the pollution of the Landak River.
Each group member thinks of one creative idea or solution to reduce the impact of pollution or prevent further damage.
Write down your solution in your personal notes to be discussed later.
Group Assignment:
Collect all ideas from group members.
Read aloud the written ideas in turn so that each member can understand one another's thoughts.
Use critical thinking skills to assess the strengths and weaknesses of each idea.
4C-Based Instructions:
Stage 5: *Uji* (Prototype Testing)
4C-Based Instructions:
Communication Skills
Listen to feedback, criticism, and suggestions from other groups or the teacher.
Record all input, both supportive and those pointing out weaknesses in your prototype.
Deliver clear arguments about why this solution is important, realistic, and beneficial to the community.

Collaboration and Critical Thinking Skills
Analyze the strengths and weaknesses of the prototype based on the feedback received.
Modify or improve the design, function, or method of delivering the solution.
Discuss together in the group whether any part of the prototype needs improvement to better suit environmental and community needs
Critical and Creative Thinking Skills
Analyze the strengths and weaknesses of the prototype based on the feedback received.
Modify or improve the design, function, or method of delivering the solution.
Critical and Creative Thinking Skills
Discuss together: which solution is the most realistic, sustainable, and has a positive impact on the environment and the preservation of the Landak River?

Collaboration Skills
Combine several ideas if possible, to produce a more innovative and comprehensive solution.
Communication Skills
Formulate one group innovative solution briefly, clearly, and logically.
Stage 4: *Marancang* (Designing a Prototype)
4C-Based Instructions:
Critical Thinking Skills
Review the innovative solution selected in the Namu Ide stage.
Analyze how the solution can be implemented by considering local wisdom, cultural values, and ancestral heritage of the communities around the Landak River.
Record the environmental and cultural aspects that must be preserved to ensure the solution remains relevant and sustainable.
Creative Thinking Skills
As a group, create an initial design of your prototype solution (for example: a campaign poster about environmental pollution, or a simple water filter made from traditional materials).
Use creativity to incorporate regional cultural elements (examples: traditional symbols, the practice of gotong royong, local proverbs about nature, rituals for protecting river water).
Collaboration Skills
Divide group tasks: who will draw, write descriptions, prepare materials, and organize the presentation.
Communication Skills
Include reasons why your design is appropriate for community needs, protects river sustainability, and simultaneously preserves local culture.

The results of the validity and reliability analysis of the Naik Dango learning model integrated with design thinking are presented in table 5.

Table 5. Results of the Validity and Reliability of the Naik Dango Learning Model Integrated with Design Thinking

No	Learning Instrument	Validity	Category	Reliability	Category
1	Student worksheet	0,91	Valid	0,70	Substantial
2	Environmental Pollution material	0,97	Valid	0,75	Substantial
3	Critical thinking skill instrument	0,88	Valid	0,80	Perfect
4	Creative thinking skill instrument	0,90	Valid	0,83	Perfect
5	Collaboration skill instrument	0,89	Valid	0,80	Perfect
6	Communication skill instrument	0,90	Valid	0,81	Perfect

Based on table 5, the validity analysis was carried out using Aiken's validity index. An aspect is considered valid if the calculated validation value meets the minimum required threshold, namely an Aiken's coefficient of 0,80. The results of the analysis indicate that all learning instruments obtained values above 0,80; thus, it can be concluded that each aspect of the Naik Dango learning model integrated with design thinking was validated by the experts. Following the validity test, a reliability test was conducted to determine the consistency of the validators in assessing the learning model. The reliability test using Fleiss' Kappa showed that all learning instruments were within the range of 0,70–0,83, leading to the conclusion that each instrument of the Naik Dango learning model integrated with design thinking falls within the categories of substantial to almost perfect agreement.

Table 6 below presents the results of the practicality evaluation of the Naik Dango learning model integrated with design thinking.

Table 6. Students' Responses to the Naik Dango Learning Model Integrated with Design Thinking

No	Observed Aspect	Percentage (%)	Criteria
1	Barage Stage	81	Very Strong
2	Karajasama Stage	82	Very Strong
3	Namu Ide Stage	92	Very Strong
4	Marancang Stage	90	Very Strong
5	Uji Stage	91	Very Strong
	Average	87,20	Very Strong

Based on table 6, students' responses to the Naik Dango learning model integrated with design thinking in the Barage phase showed a percentage of 81 %, which falls into the "very strong" category, indicating that most students perceived the benefits of togetherness in group gatherings that foster collaborative work to support one another in problem-solving. The Karajasama phase obtained a percentage of 82 %, also categorized as very strong, suggesting that students recognized their roles within the group and adjusted themselves to other members when engaging in problem-solving. The Namu Ide, Marancang, and Uji phases each achieved percentages of 92 %, 90 %, and 91 %, respectively, all categorized as very strong.

The effectiveness of the Naik Dango learning model integrated with design thinking in enhancing students' 4C skills (critical thinking, creativity, communication, and collaboration) was tested with a limited sample of 85 students. A pre-test was conducted at the beginning of the learning process to measure students' baseline levels of 4C skills, followed by a post-test after the implementation of the model to examine changes. The effectiveness of the learning model was analyzed using Ancova. Prior to this, prerequisite tests of homogeneity and normality were carried out, as presented in tables 7 and 8.

Table 7. Results of Normality and Homogeneity Tests

No.	Variable	Sig. Value	Normality Interpretation	Sig. Value	Homogeneity Interpretation
1	Critical thinking skill	0,147	Normal	0,382	Homogen
2	Creative thinking skills	0,432	Normal	0,246	Homogen
3	Communication skills	0,074	Normal	0,975	Homogen
4	Collaboration skills	0,372	Normal	0,518	Homogen

Based on table 7, the results of the normality test using the Kolmogorov-Smirnov test show that the significance values of all variables are greater than 0,05, indicating that the normality assumption is met. Meanwhile, the homogeneity test using Levene's Test shows that the significance values of all variables are also greater than 0,05, which indicates that the data meet the homogeneity criteria.

Table 8. Results of the Improvement in 4C Skills

4C Skills	Pretest Mean	Posttest Mean	Mean Difference	Sig. (2 tailed)
Critical thinking skill	50,32	75,48	25,16	0,000
Creative thinking skills	52,15	77,30	25,15	0,003
Communication skills	53,40	76,80	23,40	0,000
Collaboration skills	54,00	78,60	24,60	0,002

Table 8 presents the results of descriptive and inferential statistical analyses for students' pre-test and post-test scores. The descriptive statistics indicate that the mean post-test score was higher than the mean pre-test score, suggesting an improvement in student learning outcomes after the implementation of the Naik Dango Learning Model, which may be attributed to the development of students' 4C skills during the learning process. Furthermore, the Ancova analysis results show that the p-value was less than 0,05, indicating a significant difference between the critical thinking, creativity, communication, and collaboration skills of the experimental class, which applied the Naik Dango learning model integrated with design thinking, and the control class, which applied the Creative Problem-Solving model. Thus, the Naik Dango learning model integrated with design thinking was effective in fostering 4C skills, thereby supporting the improvement of learning outcomes in environmental pollution biology instruction.

DISCUSSION

This study focuses on the development and implementation of the Naik Dango learning model integrated with design thinking, which integrates local wisdom to empower 21st-century skills, particularly the 4C skills (critical thinking, creativity, communication, and collaboration).

Improvement of critical thinking skills

Demonstrates that the Naik Dango learning model integrated with design thinking is effective in fostering analytical and evaluative reasoning. Critical thinking has long been recognized as an essential skill for students to address complex problems and make informed decisions.[49] The Design Thinking approach, with its emphasis on empathy and problem-solving, supports the development of this skill. According to Paul et al.[50] critical thinking can be nurtured through structured inquiry, which is a core component of the Naik Dango model.

Furthermore, social constructivism[51] emphasizes that learning is enhanced through social interaction and collaborative problem-solving, both of which are integral to this model.

Improvement of creative thinking skills

This indicates that students' ability to generate innovative solutions improved after the implementation of the Naik Dango learning model integrated with design thinking. Creative thinking is essential in the 21st century because it enables students to tackle new and complex problems.[52] The Ideation phase in Design Thinking, which encourages divergent thinking and idea generation, directly supports the development of creativity.[53] Furthermore, as highlighted by Guilford[52] fostering creativity in education is crucial for addressing global challenges, as it allows students to think outside the box and develop innovative solutions.

Improvement of communication skills

This indicates that the Naik Dango learning model Integrated with design thinking enhanced students' ability to articulate their ideas and engage in meaningful discussions. Communication is a crucial 21st-century skill, as it is essential for collaboration, leadership, and successful interaction in an increasingly globalized world.[54] Johnson et al.[55] highlight the importance of collaborative learning environments in fostering communication skills, which aligns with the group-based nature of the Naik Dango learning model integrated with design thinking. Students are encouraged to communicate ideas, negotiate with peers, and present solutions effectively, thereby strengthening their verbal and non-verbal communication skills.

Improvement of collaboration skills

The improvement in collaboration skills, reflected in the score increase from 54,00 to 78,60, indicates that this model successfully promoted teamwork and cooperative problem-solving. Collaboration, as emphasized by Johnson et al.[55], is crucial for developing critical social and cognitive skills. By engaging in group activities, students learn to share ideas, manage conflicts, and work toward common goals. The Naik Dango learning model integrated with design thinking emphasis on collective action, such as in the "Karajasama" (cooperation) phase, fosters these skills in a way that mirrors real-world work environments where collaboration is essential for success.[56,57]

Statictical analysis and effectiveness of the naik dango model

The results of the Ancova test, which showed a p-value less than 0,05, provide statistical evidence that there is a significant improvement between the critical thinking, creative thinking, communication, and collaboration skills of the experimental class implemented with the Naik Dango learning model integrated with design thinking and the control class implemented with the Creative Problem Solving learning model.[58,59] This supports the hypothesis that the Naik Dango learning model integrated with design thinking has a positive impact on the development of critical thinking, creative thinking, communication, and collaboration skills. Previous studies also support the idea that problem-based and inquiry-based learning models contribute to the development of these skills. For example, Tejedor et al.[57] noted that problem-based learning enhances students' ability to think analytically and collaborate in groups.

Furthermore, the integration of local wisdom within the design thinking framework allows students to connect their learning to real-world problems, as demonstrated in the relationship between environmental factors and environmental pollution functions in student worksheets. By taking social and cultural contexts into account, the Naik Dango learning model integrated with design thinking fosters deeper understanding of the subject matter while cultivating a sense of responsibility toward social and environmental issues, as highlighted by Roberts[58] in his theory of experiential learning.

CONCLUSIONS

The Naik Dango local wisdom-based learning model integrated with Design Thinking has been successfully developed as an innovative learning strategy. This model has the potential to empower students' 4C skills critical thinking, creative thinking, communication, and collaboration within the context of learning about environmental pollution. By integrating local cultural values, learning becomes more contextual, meaningful, and relevant to students' lives. Therefore, this model can serve as an effective alternative in 21st-century education, emphasizing the development of students' thinking and collaboration skills as well as the implementation of learning that is oriented toward local contexts.

Limitations

Several limitations in the development of the *Naik Dango* learning model integrated with design thinking should be noted. First, the limitation in research coverage, which was conducted only in certain schools, so the results may not be generalizable to the broader educational context in other regions. Second, this study still

relies on questionnaire and observation instruments that may not fully capture the 4C skills (critical thinking, creative thinking, collaboration, communication) comprehensively. Third, the model trial process was carried out on a limited scale, so the long-term effectiveness of the *Naik Dango* model integrated with design thinking across various subjects or educational levels has not been fully revealed. Fourth, there are external variables such as students' backgrounds, teachers' readiness, as well as school facilities and infrastructure conditions that cannot be fully controlled and may influence the outcomes of the model implementation.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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