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Enhancing 21st-Century Learning Skills in Early Childhood through a Local Wisdom-Integrated Science, Technology, Engineering, Arts, and Mathematics (STEAM) Learning Package to Support Sustainable Development Goals (SDGs): A Bibliometric and Mixed-Methods Study

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ABSTRACT

This study examined the effect of a local wisdom-integrated science, technology, engineering, arts, and mathematics (STEAM) learning package on twenty-first-century learning skills in early childhood and positioned the topic within SDGs-oriented education through bibliometric mapping. A mixed-methods design combined bibliometric analysis, a one-group pretest-posttest design, and phenomenological observation. Forty early childhood students participated in the "Rice and Farmers" learning unit using the I-WISDOM package. Quantitative data were analyzed using dependent sample t-tests and Cohen's effect size, while qualitative data were interpreted through analytic description. The findings showed significant improvement in creativity, problem solving, communication, and collaboration. Students also demonstrated appreciation of rice farming as local wisdom. The study supports quality education, cultural sustainability, and early skill development through STEAM-based learning.

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1. INTRODUCTION

Contemporary education is expected to prepare learners for social, technological, cultural, and environmental changes that require adaptive thinking and flexible knowledge application. Learners need competencies that help them understand new information, respond to unfamiliar situations, and participate meaningfully in a future society. Educational systems, therefore, have a responsibility to develop learning skills from the earliest stages of schooling because early childhood is a foundational period for cognitive, social, and communicative development (Goodman, 1995; Cabello *et al.*, 2021).

Twenty-first-century learning skills are widely recognized as essential competencies for learners across educational levels (Thanomchaithawat *et al.*, 2016). Recent studies have discussed these skills in relation to entrepreneurship, curriculum development, sports education, and student achievement, indicating their relevance across different educational contexts (Bantilan, 2024; Ergashevna, 2025; Gatta *et al.*, 2023; Ibrahim *et al.*, 2024). Among these competencies, creativity, critical thinking, communication, and collaboration are particularly important because they help learners generate ideas, analyze situations, express understanding, and work with others. These skills should be developed from early childhood because young learners are naturally curious, exploratory, and capable of constructing meaning through play, dialogue, and hands-on experiences (Cabello *et al.*, 2021; Ergashevna, 2025).

The development of young learners' skills (specifically creativity and innovation, critical thinking and problem solving, communication, and collaboration (4C)) remains an important educational concern (Ergashevna, 2025). Early childhood classrooms need stronger support for problem solving, creative thinking, communication, and critical thinking through activities that are concrete, meaningful, and developmentally appropriate (Salman and Yahaya, 2025; Wijaya and Nandiyanto, 2022; Obafemi *et al.*, 2023). These challenges are related not only to student achievement but also to teaching approaches that may insufficiently prioritize experiential learning, integrated knowledge construction, and learner-centered activity. Therefore, early childhood education needs instructional models that encourage children to observe, explore, discuss, create, and solve problems in meaningful contexts (Cabello *et al.*, 2021; DeJarnette, 2018).

Science, technology, engineering, arts, and mathematics (STEAM) education offers a relevant pedagogical approach for developing 4C skills because it integrates science, technology, engineering, arts, and mathematics through interdisciplinary learning. STEAM learning enables children to connect concepts, materials, imagination, and practical problem-solving in authentic situations. The inclusion of the arts in Science, technology, engineering, and mathematics (STEM) is especially important for young learners because it supports creativity, visual expression, aesthetic sensitivity, and imaginative thinking. STEM is effective in increasing the quality of the teaching and learning process (Yooajin and Insombat, 2021; Silpakitjayan and Hemchayati, 2019). Indeed, STEAM education can support creativity, reasoning, communication, and problem-solving development in early childhood and basic education contexts (DeJarnette, 2018; Kim and Park, 2012; Land, 2013; Sochacka *et al.*, 2016; Monkeviciene *et al.*, 2020).

Local wisdom can strengthen learning by connecting classroom activities with learners' cultural environments and community knowledge (Lestari, 2024). Rice farming represents an important cultural, economic, and social practice that children can understand through

observation, storytelling, materials, and hands-on learning (Sumaludin, 2024). Integrating local wisdom into STEAM activities can help young learners develop twenty-first-century skills while also appreciating cultural identity and community knowledge. Such integration also supports Sustainable Development Goals (SDGs), particularly SDG 4 on quality education, SDG 11 on sustainable communities and cultural heritage, and SDG 12 on responsible production and consumption through awareness of rice production and local livelihoods (Nugroho *et al.*, 2019; Piangngok *et al.*, 2020).

Although research on STEAM education, local wisdom, and twenty-first-century skills has grown, empirical evidence on local wisdom-integrated STEAM learning packages for early childhood remains limited. Existing studies have shown the potential of local wisdom-based STEM or STEAM learning, yet fewer studies combine quantitative measurement, qualitative observation, and bibliometric positioning within an SDGs-oriented framework. Bibliometric analysis is useful for identifying the research trend and positioning this study within the wider development of STEAM education, early childhood learning, local wisdom, and sustainability-oriented education.

This study aims to investigate the effect of a local wisdom-integrated STEAM learning package on twenty-first-century learning skills among early childhood students and to position the topic within SDGs-oriented educational research through bibliometric analysis. The mixed-methods component evaluates changes in children's 4C skills before and after the intervention and explains their learning behaviors through classroom observation. The novelty of this study lies in combining the I-WISDOM learning package, local wisdom-based STEAM education, early childhood 4C skill development, bibliometric mapping, and SDGs relevance in one integrated study. This study is guided by the following research questions:

(i) How is the local wisdom-integrated STEAM learning package structured to promote twenty-first-century learning skills in early childhood?
(ii) Does the local wisdom-integrated STEAM learning package significantly improve early childhood students' 4C learning skills?
(iii) How do early childhood students demonstrate creativity, problem solving, communication, and collaboration during the learning activities?
(iv) How does bibliometric evidence position local wisdom-integrated STEAM learning within SDGs-oriented early childhood education research?

2. LITERATURE REVIEW

2.1. Twenty-First-Century Learning Skills in Early Childhood

Twenty-first-century learning skills refer to competencies that help learners respond to changing social, technological, and professional conditions. Creativity, critical thinking, communication, and collaboration enable learners to generate new ideas, examine problems, express meaning, and work with others to achieve shared goals. For early childhood learners, these skills should be developed through play-based, inquiry-based, and experience-based learning rather than through isolated content instruction. Early childhood is a crucial period for developing learning skills because children actively construct knowledge through sensory experiences, social interaction, language, and imagination. Young children need opportunities to ask questions, manipulate materials, communicate ideas, and participate in collaborative problem solving. Such activities build foundations for later learning and help children develop confidence, curiosity, and social participation (Cabello *et al.*, 2021; Ergashevna, 2025).

2.2. STEAM Education for Young Learners

STEAM education integrates science, technology, engineering, arts, and mathematics into learning activities that encourage inquiry, design, creativity, and problem solving (Ernazarov *et al.*, 2025). The concept of STEAM is presented in **Table 1**.

Table 1. Conceptual components of STEAM education in the I-WISDOM learning package.

STEAM COMPONENT	CONCEPTUAL MEANING	APPLICATION IN THE "RICE AND FARMERS" LEARNING UNIT	EXPECTED LEARNING CONTRIBUTION
Science	Understanding natural phenomena, living things, materials, and environmental processes.	Children observe rice plants, rice fields, farming stages, weather, water, soil, and living things in the rice-field environment.	Supports curiosity, observation, classification, and basic understanding of agricultural ecosystems.
Technology	Using tools, materials, and simple techniques to support learning and problem-solving.	Children explore farming tools, visual cards, learning materials, and classroom media related to rice production.	Helps children understand how tools support human work and encourages practical problem-solving.
Engineering	Designing, arranging, building, testing, and improving solutions to complete a task.	Children arrange rice farming sequences, organize procedural cards, and solve problems related to farming processes.	Develops logical sequencing, planning, problem solving, and iterative thinking.
Arts	Expressing ideas, imagination, culture, and meaning through creative representation.	Children create drawings such as "My Rice Field" and represent rice farming through visual and creative works.	Enhances creativity, imagination, aesthetic expression, and appreciation of local culture.
Mathematics	Recognizing patterns, order, quantity, comparison, spatial relation, and sequence.	Children compare objects, arrange steps in order, recognize farming sequences, and organize visual elements in learning tasks.	Supports reasoning, ordering, spatial thinking, and early mathematical understanding.
Local wisdom integration	Connecting STEAM concepts with community knowledge, cultural practice, and lived experience.	Rice farming is used as a culturally familiar context involving farmers, farming tools, rice fields, and rice as Thai local wisdom.	Builds cultural awareness, appreciation of local knowledge, and relevance of learning to daily life.

The arts component enriches STEM learning by supporting imagination, representation, and creative expression. This is important for early childhood education because young learners often express understanding through drawing, building, movement, storytelling, and symbolic play. STEAM learning, therefore, provides a developmentally appropriate way to connect knowledge with creativity and hands-on exploration (Kim and Park, 2012; Land, 2013; DeJarnette, 2018). Effective STEAM education requires more than combining subject names. It should create learning experiences in which children investigate real situations, use materials, design solutions, communicate ideas, and revise their work. Through these processes, children can develop creativity, reasoning, collaboration, and communication. STEAM learning is especially relevant when activities are connected to children's daily lives

and cultural experiences because young learners understand abstract ideas more easily when they are grounded in familiar contexts (Sochacka *et al.*, 2016; de Vries, 2021).

2.3. Local Wisdom as a Context for STEAM Learning

Local wisdom can strengthen the teaching and learning process. It connects learning activities with learners' cultural environments and community knowledge (Lestari, 2024). The local wisdom-integrated STEAM learning package in this study was developed to promote twenty-first-century learning skills among early childhood students. The package was organized around the learning unit "Rice and Farmers" and included learning activity plans, an instructional manual, learning materials, and assessment instruments. The learning activities followed four instructional stages: inspire, plan and design, act, and share and summarize. These stages were designed to encourage children to become interested in the topic, organize ideas, engage in hands-on activities, and share their learning outcomes. The package integrated science, technology, engineering, mathematics, and arts through creative materials and activities related to rice farming. It also embedded local wisdom through farming tools, rice production procedures, and cultural meanings associated with farmers and rice as the staple food of Thai people. The assessment focused on four learning skills: creativity and innovation, critical thinking and problem solving, communication, and collaboration. This structure makes the package appropriate for examining both cognitive and social learning outcomes in early childhood contexts.

2.4. The I-WISDOM Learning Package

The local wisdom-integrated STEAM learning package in this study was developed to promote twenty-first-century learning skills among early childhood students. The package was organized around the learning unit "Rice and Farmers" and included learning activity plans, an instructional manual, learning materials, and assessment instruments. The learning activities followed four instructional stages: inspire, plan and design, act, and share and summarize. These stages were designed to encourage children to become interested in the topic, design ideas, and act through hands-on activities, and share their learning outcomes. The package integrated science, technology, engineering, mathematics, and arts through creative materials and activities related to rice farming. It also embedded local wisdom through farming tools, rice production procedures, and cultural meanings associated with farmers and rice as the staple food of Thai people. The assessment focused on four learning skills: creativity and innovation, critical thinking and problem solving, communication, and collaboration. This structure makes the package appropriate for examining both cognitive and social learning outcomes in early childhood contexts.

2.5. SDGs-Oriented Early Childhood Education

SDGs-oriented education emphasizes quality learning, inclusion, sustainability, cultural relevance, and future readiness (Maryanti *et al.*, 2022). Early childhood education contributes to SDG 4 because it provides the foundation for lifelong learning and equitable educational development. Local wisdom-integrated STEAM learning also supports SDG 11 because it helps preserve and transmit cultural knowledge within communities. In addition, learning about rice and farmers can support SDG 12 by encouraging children to understand food production, local resources, and responsible appreciation of community livelihoods. The use of local wisdom in early childhood STEAM education, therefore, connects skill development with sustainability. Children not only learn how to create, communicate, and collaborate, but also

learn to value cultural knowledge and community practices. This approach is important because sustainability education should begin early and should be connected to children's lived experiences. Therefore, the I-WISDOM learning package can be positioned as an educational intervention that supports both twenty-first-century learning and SDGs-oriented cultural sustainability.

2.6. Bibliometric Positioning and Research Gap

Bibliometric analysis can help identify the development of research trends (Nandiyanto *et al.*, 2025). It can be used for understanding research related to STEAM education, early childhood learning, local wisdom, twenty-first-century skills, and SDGs. This is important because the present study not only tests an instructional intervention but also positions the topic within a broader academic landscape. By mapping publication trends, the study can show whether local wisdom-integrated STEAM learning is an emerging area and how it relates to sustainability-oriented education. The reviewed literature suggests that STEAM education supports integrated learning, local wisdom provides cultural relevance, and early childhood is a key stage for developing 4C skills. However, there remains a need for studies that combine local wisdom-integrated STEAM learning packages, mixed-methods evidence, bibliometric positioning, and SDGs relevance. The synthesis of the literature and research gap is summarized in **Table 2**.

Table 2. Synthesis of literature and research gap.

THEME	MAIN IDEA FROM LITERATURE	RELEVANCE TO THIS STUDY	IDENTIFIED GAP
Twenty-first-century skills	Early learners need creativity, problem solving, communication, and collaboration.	The study evaluates 4C skills as the main learning outcome.	Limited evidence explains how integrated local wisdom-based packages improve 4C skills in early childhood.
STEAM education	STEAM integrates science, technology, engineering, arts, and mathematics through inquiry and creative activity.	The I-WISDOM package uses STEAM activities in the "Rice and Farmers" unit.	More evidence is needed on STEAM learning packages designed specifically for early childhood.
Local wisdom	Local wisdom connects learning with cultural practices, community knowledge, and identity.	The study uses rice farming as a Thai local wisdom context.	Few studies integrate local wisdom, STEAM, and 4C assessment in one early childhood intervention.
SDGs-oriented education	Sustainable education promotes quality learning, cultural continuity, and responsible understanding of local resources.	The study links the package to SDG 4, SDG 11, and SDG 12.	SDGs are often discussed generally, but less often connected to early childhood STEAM activity outcomes.
Bibliometric positioning	Bibliometric analysis identifies research trends and positions, and emerging topics.	The study includes bibliometric mapping to frame the topic academically.	Limited studies combine bibliometric evidence with mixed-methods intervention research on local wisdom-integrated STEAM learning.

3. METHODS

3.1. Bibliometric Procedure

Bibliometric analysis was conducted to position this study within the research trend on twenty-first-century skills and STEAM education. The bibliographic data were collected from the Scopus database using the search query TITLE-ABS-KEY (21st AND skills AND steam AND education). The search covered publications from 2012 to 2025 and identified 149 documents. The analysis focused on annual publication trends to examine the development of research related to STEAM education and twenty-first-century skills. The bibliometric data were interpreted descriptively by reviewing the number of documents published each year. The annual trend was used to determine whether research on STEAM education and twenty-first-century skills has increased over time. The results of this analysis were then connected to the present mixed-methods findings to show how the I-WISDOM learning package contributes empirical classroom evidence to an expanding research area. This bibliometric component also supported the discussion of SDGs-oriented education because the development of twenty-first-century skills through STEAM learning is closely related to quality education, cultural sustainability, and future learning readiness.

3.2. Research Design

The quantitative component employed a one-group pretest-posttest design. This design was used to compare students' 4C learning skills before and after the implementation of the I-WISDOM learning package. The qualitative component described students' learning experiences during the activities based on classroom observation and field notes. The results from both components were interpreted together to provide a more complete understanding of the effect of the intervention.

3.3. Population and Sample

The population consisted of early childhood students at Khon Kaen University Demonstration School in Khon Kaen Province, Thailand. The school had six mixed-ability classrooms, with forty students in each classroom, resulting in a total population of 240 students. The sample consisted of one classroom of forty early childhood students. Cluster random sampling was used to select the sample.

3.4. Learning Package and Intervention

The intervention used a local wisdom-integrated STEAM learning package called the I-WISDOM package. The package was developed to promote twenty-first-century learning skills among early childhood students through activities that integrated science, technology, engineering, arts, mathematics, and Thai local wisdom. The package was organized around the learning unit "Rice and Farmers" and consisted of four main components: learning activity plans, an instructional manual, learning materials, and learning skills assessment instruments.

The learning activity plan consisted of ten plans requiring ten hours of instruction. The learning activities were implemented through four instructional stages.

(i) Stage 1: Inspire. This stage was designed to stimulate children's curiosity and interest in rice, farmers, and local wisdom. Children were introduced to the topic through concrete experiences, questions, visual materials, and discussion related to rice farming and Thai community life.

(ii) Stage 2: Plan and design. This stage encouraged children to organize ideas, plan learning tasks, and design creative responses. Children were guided to think about rice farming processes, choose materials, arrange ideas, and prepare for hands-on STEAM activities.

(iii) Stage 3: Act. This stage allowed children to participate in hands-on STEAM activities using learning materials related to rice farming. Children observed, created, arranged, solved problems, communicated, and collaborated while engaging with tasks connected to the "Rice and Farmers" learning unit.

(iv) Stage 4: Share and summary. This stage encouraged children to present their work, explain their ideas, listen to peers, reflect on the learning process, and summarize what they learned from the activities. This stage also supported communication, collaboration, and appreciation of rice farming as local wisdom.

The instructional manual guided the implementation of the learning activity plans. It included explanations of the learning principles, objectives, instructional steps, teacher roles, classroom interaction, support system, and assessment procedures. The manual was used to ensure that the learning activities were implemented consistently and aligned to develop twenty-first-century learning skills.

The learning materials consisted of ten creative material sets used together with the ten learning activity plans. These materials integrated local wisdom related to rice farming, including farming procedures, local tools, and cultural knowledge connected to Thai agricultural practices. The materials helped children understand rice as the staple food of Thai people and recognize farmers as important members of the community. Through these activities, children were expected to develop creativity and innovation, critical thinking and problem solving, communication, and collaboration while also appreciating local wisdom and cultural continuity.

The learning skills assessment instrument was also included as part of the package. It was used to evaluate students' 4C learning-skill behaviors, namely creativity and innovation, critical thinking and problem solving, communication, and collaboration. The assessment was conducted before, during, and after instruction to capture both formative learning behaviors and summative learning outcomes. The instrument used a five-level rating scale from 0 to 4.

(i) A score of 4 indicated that the student demonstrated the target learning-skill behavior clearly and consistently while engaging in learning activities.

(ii) A score of 3 indicated a clear demonstration of the behavior during learning activities.

(iii) A score of 2 indicated an occasional clear demonstration of the behavior.

(iv) A score of 1 indicated limited demonstration of the behavior.

(v) A score of 0 indicated that the target behavior was not demonstrated during the activity.

3.5. Research Instruments

The research instruments consisted of the I-WISDOM learning activity package, a twenty-first-century learning skills assessment tool, and a learning behavior observation form. The learning activity package included the "Rice and Farmers" unit, ten activity plans, learning materials, and an instructional manual. The assessment tool measured four 4C learning skills: creativity and innovation, critical thinking and problem solving, communication, and collaboration. The assessment tool used a rating scale to evaluate students' learning skill behaviors during the activities. The scoring criteria ranged from no demonstration of the

target behavior to clear and consistent demonstration of the behavior. The learning behavior observation form was used to collect qualitative evidence of students' learning experiences, including verbal interactions, peer collaboration, creative work, problem-solving processes, and communication during the activities.

3.6. Data Collection Procedure

Data collection was conducted in three stages:

(i) First, students' twenty-first-century learning skills were assessed before the intervention. The pretest assessment focused on creativity and innovation, critical thinking and problem solving, communication, and collaboration. Three assessors were involved in the evaluation process: one classroom teacher and two observer teachers.

(ii) Second, the I-WISDOM learning package was implemented with the sample group. The intervention used the "Rice and Farmers" learning unit and ten learning activity plans. During the implementation, researchers and research assistants observed students' learning behaviors and recorded field notes. The observations focused on how students demonstrated the 4C skills during authentic classroom activities.

(iii) Third, students' twenty-first-century learning skills were assessed after the intervention using the same assessment framework. The posttest assessment also involved three assessors. The pretest and posttest results were then analyzed quantitatively, while observation records were analyzed qualitatively to explain how the 4C skills appeared during learning.

3.7. Data Analysis

Quantitative data were analyzed using descriptive and inferential statistics. Mean scores and standard deviations were calculated to describe students' 4C learning skills before and after the intervention. A dependent sample t-test was used to examine whether posttest scores were significantly higher than pretest scores. Cohen's d was calculated to determine the magnitude of the learning improvement. Detailed information regarding t-test analysis is reported elsewhere (Nandiyanto and Hofifah, 2024).

4. RESULTS AND DISCUSSION

4.1. Quantitative Improvement in Twenty-First-Century Learning Skills

The implementation of the local wisdom-integrated STEAM learning package, designated as the I-WISDOM package, produced a significant improvement in early childhood students' twenty-first-century learning skills. The quantitative results are presented in **Table 3**. The posttest mean score was higher than the pretest mean score, indicating that students demonstrated stronger 4C learning skills after participating in the "Rice and Farmers" learning unit. The dependent sample t-test showed a statistically significant difference between pretest and posttest scores at the .01 level. This result confirms that the learning package effectively supported the development of creativity and innovation, critical thinking and problem solving, communication, and collaboration.

Early childhood students obtained a posttest mean score of 3.01 with a standard deviation of 0.26 after participating in the I-WISDOM learning package. This score indicates a high level of 4C learning-skill performance. The posttest result was substantially higher than the pretest mean score of 2.31 with a standard deviation of 0.26, which indicated a moderate level of

performance before the intervention. These results provide empirical evidence that the local wisdom-integrated STEAM learning package effectively enhanced early childhood students' twenty-first-century learning skills, especially creativity and innovation, critical thinking and problem solving, communication, and collaboration.

Table 3. Effects of implementing the I-WISDOM learning package on twenty-first-century learning skills.

PERIOD	NUMBER OF STUDENTS	M	SD	T	DF	SIG.
Posttest	40	3.01	0.26	26.86	39	0.00**
Pretest	40	2.31	0.26			

Note: **p < 0.01.

The magnitude of improvement was further examined using Cohen's d effect size. The calculation was conducted by subtracting the pretest mean score from the posttest mean score and dividing the result by the pooled standard deviation. The mean difference was 0.70, obtained from 3.01 minus 2.31. The pooled standard deviation was 0.26. Therefore, Cohen's d was calculated as 0.70 divided by 0.26, resulting in a value of 2.69. This value represents a very large effect size, indicating that the learning package had a strong practical effect on students' 4C learning-skill development.

The large effect size supports the statistical hypothesis testing result, which showed a significant difference between pretest and posttest scores at the .01 level. The convergence of statistical significance and effect size evidence confirms that the I-WISDOM learning package substantially improved students' twenty-first-century learning skills. This improvement can be explained by the structure of the package, which integrated STEAM education with the culturally familiar "Rice and Farmers" learning unit. Children were not only asked to remember information about rice farming but also to observe, create, discuss, arrange, solve problems, and share ideas. This type of active and culturally meaningful learning can strengthen children's ability to think, communicate, collaborate, and solve problems when learning is grounded in concrete experiences (Cabello et al., 2021; Ergashevna, 2025).

Furthermore, qualitative data collected from classroom observations revealed how the 4C skills appeared in authentic learning contexts. Students demonstrated creativity and innovation, critical thinking and problem solving, communication, and collaboration during the implementation of the learning package. The following sections present representative photographic evidence and classroom vignettes to illustrate the emergence of these competencies during instruction.

4.2. Creativity and Innovation

Qualitative observation showed that students demonstrated creativity and innovation through the activity "My Rice Field," as presented in **Figure 1**. Students created personalized drawings related to rice fields, farmers, natural elements, animals, and farming environments. Their works showed different interpretations of the rice-field ecosystem, including grass, mountains, rice plants, clouds, crabs, scarecrows, and huts. These creative variations indicate that the learning package provided space for children to express individual ideas and construct visual meaning from the local wisdom context.

There are some comments from students:

(i) Student 1: "There are grass, mountains, rice, and clouds in the rice fields."

(ii) Student 2: "There are a crab, a scarecrow, and a hut in the rice fields."

The creativity shown in **Figure 1** indicates that the arts component in STEAM helped children transform their understanding of rice farming into a visual expression. This supports the idea that integrating arts into STEM can enrich children's imagination and creative thinking. The local wisdom theme also helped children build creative ideas from a meaningful cultural context rather than from abstract content alone. This finding is consistent with previous studies showing that STEAM education can promote creativity by combining scientific inquiry, artistic expression, and hands-on activity (Kim and Park, 2012; Land, 2013; DeJarnette, 2018).

(a) (b)

Figure 1. Student work reflecting creativity.

4.3. Critical Thinking and Problem Solving

Students demonstrated critical thinking and problem-solving skills through activities requiring them to sequence the stages of rice farming. During the activity, students observed visual representations, arranged farming procedures in chronological order, questioned the accuracy of their decisions, and verified the sequence through peer discussion. Their dialogue showed reasoning processes, such as identifying that harvesting must occur before threshing. This indicates that students were able to analyze relationships, test ideas, and justify their reasoning. Students engaged in collaborative problem-solving and verification processes, as evidenced by the following verbal protocols.

(i) Student 1 reasoned: "I think harvesting must come before threshing the rice."

(ii) Student 2 responded with a critical inquiry: "Is that correct? Let's examine it carefully."

(iii) Student 3 confirmed through logical analysis: "Yes, that's right. We must harvest first, then proceed to threshing."

The sequencing activity required children to think systematically about agricultural processes. Instead of simply naming farming activities, students needed to understand the order and relationship between each stage. This form of learning supported problem-solving

because children had to make decisions and check whether their answers were logical. The finding supports the importance of STEAM learning activities that provide authentic problems and encourage children to reason through concrete tasks (Herro *et al.*, 2017; Onpui and Treewong, 2020).

4.4. Communication

Students demonstrated communication skills by explaining their ideas, asking questions, and responding to peers during the rice farming sequencing activity. Their verbal exchanges showed that they could express opinions, clarify understanding, and participate in shared meaning-making. For example, students discussed whether harvesting should come before threshing, questioned the sequence, and confirmed the answer through group interaction. These exchanges demonstrate the use of language as a tool for learning and collective reasoning.

During the problem-solving activity involving the sequencing of rice farming procedures, students engaged in communicative exchanges to construct shared understanding, as documented in the following verbal protocols.

(i) Student 1 asserted: "Harvesting the rice must come before threshing."
(ii) Student 2 questioned critically: "Is that correct? Let's examine it carefully."
(iii) Student 3 confirmed and elaborated: "Yes, that's right. We must harvest first, this one, and then proceed to threshing."
(iv) Student 2 acknowledged agreement nonverbally and verbally: "Hmm." (nodding in affirmation)

Communication is important in early childhood learning because children develop understanding through social interaction and verbal expression. The I-WISDOM package encouraged communication by requiring children to share ideas, explain reasoning, and respond to others. This finding shows that local wisdom-integrated STEAM activities can create opportunities for meaningful dialogue among young learners. Such communication supports not only language development but also collaborative understanding and problem-solving processes in early learning contexts (Cabello *et al.*, 2021; Ergashevna, 2025).

4.5. Collaboration

Students demonstrated collaboration when they worked together to arrange procedural cards showing the stages of rice farming. The activity required students to coordinate actions, distribute roles, listen to peers, and negotiate the correct placement of visual elements. The students' dialogue showed collaborative behaviors, including directing, encouraging, observing, and helping one another. These behaviors indicate that students understood collaboration as a shared process for completing a task more effectively. The students' collaborative discourse is documented in the following verbal protocols.

(i) Student 1 directed: "Place this one here."
(ii) Student 2 encouraged collective participation: "Let's help each other."
(iii) Student 3 prompted analytical attention: "Look at the people and the background."
(iv) Student 4 provided procedural guidance: "Place it in the correct position."
(v) Student 5 articulated the value of teamwork: "When we help each other, we finish quickly."

The collaborative activity supported social learning because children needed to combine individual ideas with group decision-making. Students did not work in isolation; instead, they solved the task through peer interaction and mutual support. This finding aligns with the

concept that early childhood learning should provide opportunities for children to work with others, negotiate meaning, and develop social responsibility. It also supports previous research indicating that STEAM activities can encourage collaboration when students are engaged in shared design or problem-solving tasks (Herro *et al.*, 2017; Sochacka *et al.*, 2016).

4.6. Discussion

The I-WISDOM learning package was effective because it integrated three important elements: STEAM education, local wisdom, and active early childhood pedagogy. STEAM education provided interdisciplinary learning experiences; local wisdom provided cultural relevance; and the activity-based package provided developmentally appropriate learning opportunities. The learning unit "Rice and Farmers" allowed children to connect school learning with Thai cultural knowledge, food production, and the role of farmers in society. This connection helped students understand not only learning content but also the value of local wisdom. The findings support the view that STEM and STEAM education can develop learning competencies when students engage in integrated, creative, and hands-on activities (DeJarnette, 2018; Kim and Park, 2012; Land, 2013; Sochacka *et al.*, 2016).

The addition of the arts strengthened creative expression and enabled children to communicate ideas visually. This is important in early childhood because children often express understanding through drawing, construction, storytelling, and play. Therefore, STEAM learning is more suitable than content-based instruction for developing 4C skills among young learners. The integration of local wisdom also strengthened the educational value of the package. Rice farming is closely connected to Thai culture, livelihood, food, and community identity. By learning through the "Rice and Farmers" unit, students were able to appreciate rice production and understand farmers as important members of society. This supports previous research showing that local wisdom-based learning can enhance student outcomes and promote appreciation of community knowledge (Nugroho *et al.*, 2019; Piangngok *et al.*, 2020).

4.7. Bibliometric Analysis

The bibliometric analysis was conducted using the Scopus database with the search query TITLE-ABS-KEY (21st AND skills AND steam AND education). The search covered publications from 2012 to 2025 and identified 149 documents. The annual publication trend is presented in **Figure 2**. The results show that research related to twenty-first-century skills and STEAM education was still limited during the early period of publication, with only small annual outputs from 2012 to 2018. The number of publications began to increase more clearly after 2019, indicating growing scholarly attention to the integration of STEAM education and twenty-first-century skills. **Figure 2** shows that the number of documents increased from 1 document in 2017 to 4 documents in 2018, 11 documents in 2019, 11 documents in 2020, 16 documents in 2021, 18 documents in 2022, 19 documents in 2023, 23 documents in 2024, and 38 documents in 2025. This upward trend indicates that STEAM education has increasingly been positioned as a relevant approach for developing twenty-first-century learning skills. In the context of this study, the bibliometric results support the urgency of developing learning packages that integrate STEAM education with meaningful local contexts. Therefore, the I-WISDOM package contributes classroom-level empirical evidence to an expanding research area by showing how local wisdom-integrated STEAM activities can enhance creativity, critical thinking, problem solving, communication, and collaboration among early childhood students.

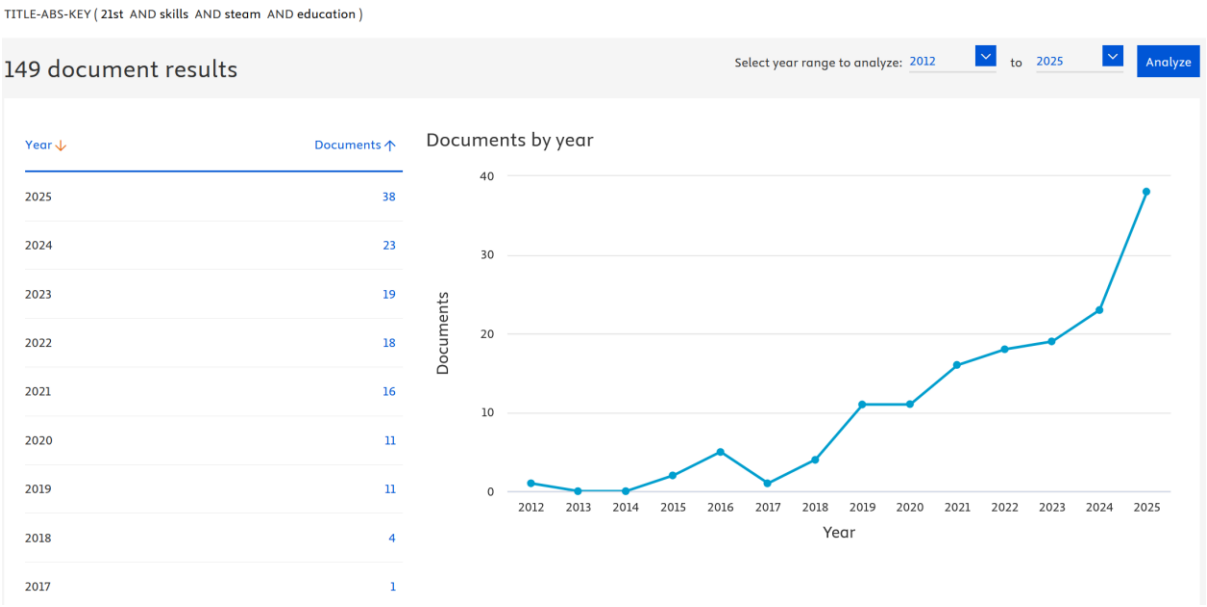

Figure 2. Bibliometric trend of publications related to twenty-first-century skills and STEAM education based on the Scopus search query TITLE-ABS-KEY (21st AND skills AND steam AND education) from 2012 to 2025. The figure shows 149 document results and an increasing publication trend, especially after 2019, with the highest annual output recorded in 2025. Data were obtained in June 2026.

4.8. SDGs Relevance

The I-WISDOM learning package is relevant to SDGs because it supports quality education, cultural sustainability, community awareness, and responsible understanding of local food production (**Table 4**). The strongest contribution is related to SDG 4 because the package improved young learners' creativity, problem solving, communication, and collaboration. It also supports SDG 11 because the package integrates local wisdom and helps preserve cultural knowledge related to rice farming. In addition, the learning unit supports SDG 12 because students learned to value rice production, farmers, and responsible appreciation of local resources. The I-WISDOM package contributes to SDGs-oriented early childhood education by combining learning-skill development with cultural and sustainability awareness. The package helps children learn through local contexts while developing competencies needed for future learning. Therefore, local wisdom-integrated STEAM education can serve as a practical approach for connecting early childhood pedagogy with sustainable education goals.

4.9. Recommendations for Future Research

Future research should examine the retention and sustainability of learning outcomes after the implementation of local wisdom-integrated STEAM learning packages for promoting twenty-first-century learning skills in early childhood. Further studies should also investigate the scalability of the I-WISDOM package across different schools, regions, and early childhood education contexts. In addition, future research should explore how deeply children develop an appreciation for local wisdom through STEAM-based activities. Such an investigation would provide clearer insight into the potential of this pedagogical approach to support the preservation and intergenerational transmission of indigenous knowledge while contributing to educational development and cultural continuity.

Table 4. Relevance of the I-WISDOM learning package to selected SDGs.

SDG	RELEVANCE TO THIS STUDY	CONTRIBUTION OF THE I-WISDOM LEARNING PACKAGE
SDG 4: Quality education	Early childhood education needs meaningful learning activities that develop essential skills.	Enhances creativity, critical thinking, communication, and collaboration through local wisdom-integrated STEAM activities.
SDG 11: Sustainable cities and communities	Local wisdom and cultural heritage should be preserved and transmitted across generations.	Introduces children to rice farming knowledge, farmers' roles, and Thai cultural identity.
SDG 12: Responsible consumption and production	Children should understand the value of food production and local resources.	Encourages appreciation of rice production and the work of farmers as part of community livelihood.
SDG 15: Life on land	Agricultural learning can support awareness of land, plants, and human relationships with nature.	Helps children learn about rice fields, farming procedures, and natural elements in the local environment.
SDG 17: Partnerships for the goals	Sustainable learning benefits from cooperation among schools, teachers, communities, and universities.	Connects school learning, university-based curriculum development, teacher support, and community-based local wisdom.

5. CONCLUSION

The local wisdom-integrated STEAM learning package effectively enhanced twenty-first-century learning skills among early childhood students. The posttest results were significantly higher than the pretest results, with a very large effect size, indicating strong improvement in creativity, critical thinking and problem solving, communication, and collaboration. Qualitative observations confirmed that children expressed creative ideas, reasoned through rice farming sequences, communicated with peers, and worked collaboratively. The package also helped children appreciate rice farming as Thai local wisdom. These findings support SDGs-oriented early childhood education through quality learning, cultural sustainability, and responsible awareness of local livelihoods.

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7. AUTHORS' NOTE

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

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