Validation of an Innovative Learning Model: Deep Learning Based on Eco-STEAM and Edutainment for Elementary School Science Education

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Abstract: Science education at the elementary school level requires an approach that can improve conceptual understanding and higher-order thinking skills, such as computational thinking. A Deep Learning-based learning model integrated with Eco-STEAM and Edutainment has the potential to facilitate more in-depth, contextual, and engaging science learning. This study aims to test the validity of this learning model for application in elementary schools. The approach used is research and development (R&D) with validation techniques by three education experts through the first stage for initial assessment and the second stage after revisions based on expert input. The results show that the developed learning model obtained an average score of 148.4 out of 175 in the first stage (valid category) and increased to 160.9 in the second stage (highly valid category) after improvements were made to several model components. The discussion shows that this model effectively integrates deep learning with the Eco-STEAM approach and edutainment media, which supports students' understanding of science concepts while developing their CT skills and ecological awareness. This study implies that this model can be implemented in science learning in elementary schools, considering further revisions involving field implementation and adjustments to local characteristics and school infrastructure.

Keywords: Deep Learning; Eco-STEAM; Edutainment; Model Validity; Science Education.

Introduction

Science education at the elementary school level is an important foundation for shaping students' scientific literacy and thinking skills from an early age (Anita et al., 2023; Astimar et al., 2019; Y. Fitria et al., 2021; Y. F. Fitria & Kenedi, 2021; Y. Fitria & Kenedi, 2022; Hendri et al., 2021). Good science learning not only emphasizes cognitive aspects but must also develop higher-order thinking skills such as computational thinking (CT) (Atmojo et al., 2018; Jones et al., 2022; Oppermann et al., 2021; Roberts, 2021; Toli & Kallery, 2021; Wangid et al., 2021). CT encompasses logical thinking, problem solving, data analysis, and algorithmic understanding, which are highly relevant in facing the challenges of the current digital era (Lodi & Martini, 2021). Integrating these skills in science learning encourages students to understand science as a collection of facts and an applicable scientific thinking process.

An appropriate pedagogical approach is needed to achieve a deep understanding of science concepts (Asrizal et al., 2023; Charles et al., 2024; Chu et al., 2021; Lee & Yang, 2020; Mercier, 2024; Oudbier et al., 2022; Zuryanty et al., 2019). One approach that has received widespread attention is deep learning, which emphasizes conceptual understanding, interconnections between ideas, and applying knowledge in authentic contexts (Ahmad et al., 2025; Akmal et al., 2025; Wang et al., 2024; Xie et al., 2023). Deep learning differs from surface learning, which only emphasizes memorization without deep understanding (Wang et al., 2024). In science learning, this approach encourages students to engage in scientific exploration, reflective discussion, and problem-solving based on phenomena that occur in everyday life.

In addition, the Eco-STEAM (Science, Technology, Engineering, Arts, Mathematics based on environmental literacy) approach provides a strategic framework for integrating interdisciplinary learning with environmental issues. This approach emphasizes building students' ecological awareness while developing creative and collaborative thinking skills. Eco-STEAM bridges conceptual science learning with sustainability values and concrete actions for the environment (Pratiwi et al., 2024). On the other hand, Edutainment, as a combination of education and entertainment, brings a new dimension to the learning process, especially for elementary school students. Interactive edutainment-based media, such as educational games, animations, or interactive simulations, have significantly increased student engagement, motivation, and conceptual understanding (Hussein et al., 2019).

However, despite numerous studies examining the integration of STEAM, CT, and Edutainment in learning, there is still a gap in the validation of learning models that combine the three in an integrated manner, especially in the context of science learning in elementary schools. Some relevant previous studies include:

First, a study by Camacho-Tamayo and Bernal-Ballen validated instruments for teachers' perceptions of the STEAM approach (Camacho-Tamayo & Bernal-Ballen, 2023). Although the instrument had high validity (KMO = 0.903), the focus of the study was still limited to perceptions, not the validation of the learning model. Second, Hsu et al. (2023) developed a "STEAM Creation" assessment model using the PLS-SEM approach to measure student design and creativity in STEAM projects (Hsu et al., 2023). However, it did not include the integration of Edutainment or environmental literacy. Third, through a systematic review, Yim et al. (2024) stated that although STEAM practices are

growing in elementary schools, most existing models have not been fully validated regarding structure, content, and pedagogical effectiveness. The effectiveness of a programming-based teaching model in improving students' CT. However, the study did not examine the comprehensive validity of the learning model design. Finally, a study by Paraskevopoulou-Kollia et al. (2025) found that few CT learning interventions at the elementary level evaluate the validity of integrated learning approaches based on STEAM and Edutainment (Paraskevopoulou-Kollia et al., 2025).

These five studies confirm that despite numerous efforts to develop STEAM and CT approaches, no study has examined the validity of learning models that fully integrate deep learning, Eco-STEAM, and edutainment approaches for science learning in elementary schools. This study aims to bridge this research gap.

The novelty of this study lies in its focus on the validity of the previously developed deep learning-based learning model, with the integration of Eco-STEAM and edutainment elements in the context of science learning. This validation covers model structure, science content suitability, the feasibility of integrating environmental literacy, the effectiveness of the edutainment media used, and implementation guidelines designed for teachers. Thus, this study contributes theoretically to developing innovative learning models and practically by providing a valid model ready for implementation in elementary schools.

The main objective of this study is to test the validity of the Eco-STEAM-based Deep Learning learning model integrated with Edutainment in science learning in elementary schools. Validation was carried out through assessments by experts in science education, learning technology, and elementary education, using validation sheets and interviews. This research is expected to strengthen the conceptual and applicative foundations of the previously developed model and provide a scientific basis for its use in the real context of elementary education in Indonesia.

Method

This research is part of a research and development phase focused on testing the validity of the Eco-STEAM-based Deep Learning learning model integrated with Edutainment. It uses a quantitative and qualitative descriptive approach, based on expert assessment, to assess the extent to which the developed model meets the feasibility criteria in terms of content, structure, media, and implementation.

Research Subjects

The subjects in this study consisted of three education experts, who were selected using purposive sampling based on their expertise and experience in relevant fields. The names and areas of expertise of each validator are as follows: Dr. Ronald Fransyaigu, M.Pd. — expert in Science Education and the development of science learning models at the elementary school level; Dr. Bunga Mulyati, M.Pd. — an expert in Learning Technology and interactive media based on Edutainment; and Dr. Asnawi, M.Pd. — an academic and researcher in elementary school curriculum and Eco-STEAM-based integrative approaches.

All three validators hold doctoral degrees (Ph.D.), have research experience, and are actively involved in academic development and publication in basic education, particularly learning innovation and technology integration.

Research Location

The validation process was conducted online and offline at various institutions where the validators work. The learning model to be validated had been developed previously and presented in narrative documents, teaching tools, and edutainment media prototypes.

Data Collection Instruments and Techniques

Data collection was conducted using two types of instruments, namely: Expert Validation Sheet, in the form of a quantitative questionnaire based on a Likert scale (1–5), covering seven aspects of the model being assessed: Structure of the learning model; Integration of the deep learning approach; Eco-STEAM components; Edutainment media; Suitability for elementary school student characteristics; Implementation guidelines; and Assessment and evaluation instruments. Open interviews were conducted to explore more in-depth qualitative input from experts regarding the strengths, weaknesses, and suggestions for model improvement.

Table 1. assessment scores categories of validation

Score	Categories
1	highly unsuitable
2	not suitable
3	somewhat suitable
4	suitable
5	highly suitable

Data Analysis Techniques
Quantitative Analysis

Quantitative data from the validation scores are calculated using the formula:
X = total average score
X_i = ideal average = ½ (maximum total score + minimum total score)

SB_i = ideal standard deviation = ⅙ (total maximum score – total minimum score)

Furthermore, the average results are categorized into five levels of validity as shown in Table 1.

Table 2. Learning Model Validity Categories

Score Range	Value	Validity Category
$X \geq X_i + 1.80\ SB_i$	A	Highly Valid
$X_i + 0.60\ SB_i \leq X < X + 1.80\ SB_i$	B	Valid
$X_i - 0.60\ SB_i \leq X < X_i + 0.60\ SB_i$	C	Sufficiently Valid
$X_i - 1.80\ SB_i \leq X < X_i - 0.60\ SB_i$	D	Less Valid
$X < X_i - 1.80\ SB_i$	E	Highly Invalid

Qualitative Analysis

Open-ended comments and interview results were analyzed thematically to reinforce and clarify the quantitative results. The steps included: Reduction of comment data and interview transcripts; Grouping by theme (structure, content, media, implementation); and Compilation of in-depth narrative findings. Input from validators was used as the basis for model revision recommendations before limited field testing.

Result and Discussion

Result

This study aims to test the validity of a previously developed learning model, namely the Eco-STEAM-based Deep Learning Model integrated with Edutainment. This model was developed to be applied in science learning at the elementary school level, emphasizing the integration of *deep* learning, eco-literacy, and technology through interactive edutainment media. Before the model was implemented in field trials, it underwent a validation stage by experts to ensure the suitability of its content, structure, and implementation.

The validation was conducted by three education experts, namely: Dr. Ronald Fransyaigu, M.Ed.,; Dr. Bunga Mulyati, M.Pd., and Dr. Asnawi, M.Ed., each of whom has expertise in the fields of science education, learning technology, and STEAM-based curriculum development in elementary education. This learning model was developed based on the learning design structure by Joyce, Weil, & Calhoun (2011), which consists of five main components.

The learning steps include: Stimulation (stimulation of the ecological context); Problem Orientation: Data Exploration with Edutainment Tools; Concept Construction; Deep Practice and Eco-Reflection; and Evaluation and Transfer.

Social System

Learning is designed to be collaborative and student-centered. Teachers act as facilitators who encourage reflective and exploratory discussions. Teachers provide feedback through open-ended questions and in-depth dialogue that trigger conceptual understanding, strengthen critical thinking, and foster empathy toward environmental issues. Learning media includes animations, short videos, simulations, environment-based worksheets, and digital tools (tablets, projectors, audio).

Instructional and Accompanying Impact

Direct impacts include improved mastery of science concepts and computational thinking. Accompanying impacts include increased environmental awareness, creativity, and social skills.

The model was validated in two stages. Stage I was the initial validation used to identify substantial weaknesses in the model. After that, revisions and improvements were made based on expert input, then continued to Stage II to confirm the improvement in the quality of the model.

Table 3. Summary of Learning Model Validation Results

Learning Model Components	Average Score in Stage I	Category	Average Score Stage II	Category	Revisions Made
Learning Model Structure	21.3 / 25	B (Valid)	23.4 / 25	A (Highly Valid)	Syntax is detailed and supplemented with concrete examples
Deep Learning Integration	20.9 / 25	B (Valid)	22.8 / 25	A (Highly Valid)	Strengthened at the reflection and transfer stage
Eco-STEAM components	21.2 / 25	B (Valid)	23.1 / 25	A (Highly Valid)	Ecological aspects are adapted to the local context
Edutainment Media	20.1 / 25	B (Valid)	21.7 / 25	B (Valid)	Plus animations and digital simulations
Suitability for Elementary School Student Characteristics	22.8 / 25	A (Highly Valid)	24.1 / 25	A (Highly Valid)	No revisions (accepted immediately)
Model Implementation Guide	21.5 / 25	B (Valid)	23.3 / 25	A (Highly Valid)	Additional technical guidance and usage scenarios
Assessment and Evaluation Instruments	20.6 / 25	B (Valid)	22.6 / 25	A (Highly Valid)	The rubric format has been clarified and adjusted again
Total Average	148.4 / 175	B (Valid)	160.9 / 175	A (Highly Valid)	

Based on Table 3, in phase I, the model was assessed as having a strong basic structure, but needed improvement in syntax, integration of Eco-STEAM content, and edutainment media format. Experts emphasized the need to contextualize ecological content with the local conditions of students and to improve the clarity of the usage guidelines in the classroom.

Based on this, several improvements were made, including: The syntax was rearranged by adding a thematic science learning flow; The *Eco-Literacy* component was clarified in the form of local exploration activities (e.g., school waste or energy issues); and Interactive animation-based media was added to enrich the students' learning experience.

In Phase II, these revisions were confirmed by experts as a significant improvement. Components that were previously only "valid" (category B) have now been upgraded to "highly valid" (category A) in almost all aspects.

Based on the results of the two validation stages, the Eco-STEAM-based Deep Learning learning model integrated with edutainment showed excellent quality and met the criteria for substantive and technical feasibility. All validators stated that this model has strong potential for application in elementary school science learning, as it is able to combine deep learning, environmental literacy, and learning technology that is appropriate for the characteristics of elementary school-aged children. These findings provide a strong basis for continuing research in the field implementation trial stage.

Discussion

This study aims to test the validity of the Eco-STEAM-based Deep Learning learning model integrated with Edutainment developed for science learning at the elementary school level. Based on the results of a two-stage validation by three education experts, it is known that this model meets the content validity criteria, both in terms of structure, integration of approaches, suitability to student characteristics, and completeness of implementation guidelines. The overall average score increased from 148.4 in stage I to 160.9 in stage II out of a maximum score of 175. Almost all components of the

model experienced an increase in validity category from "Valid (B)" to "Highly Valid (A)", indicating that revisions based on validators' input succeeded in substantially strengthening the quality of the model.

These findings are in line with the research objective, which is to ensure that the developed model is feasible and can be implemented in science learning in elementary schools. This model emphasizes meaningful learning through deep learning, the integration of eco-literacy values, and the use of edutainment media to strengthen student motivation and engagement. The relevance of this approach is reinforced by a study by Hsu et al. (2023), which states that the integration of *computational thinking* (CT), literacy, and STEAM-based design can improve students' higher-order thinking skills if designed with strong construct validity principles.

Furthermore, this developed learning model also addresses criticism of science learning, which still tends to be oriented towards memorization and technical procedures, and lacks space for exploration of local issues such as the students' surrounding environment. The Eco-STEAM approach allows students to build contextual and relevant scientific understanding, as shown by the research by Yunita et al. (2025), which states that the development of ecoliteracy-based digital media in science learning is proven to be valid and effective in increasing students' environmental awareness .

In addition, the use of edutainment as a medium to strengthen learning motivation has also proven to be effective, as explained in the study by Küçük et al. (2023), which states that *progressive STEAM-based* learning combined with educational games can encourage an increase in mathematical understanding and attitudes towards science. This is relevant to the condition of elementary school students, who tend to have visual and kinesthetic learning styles and need interactive media to build engagement.

From a model structure perspective, the update to the learning syntax to six stages—starting from stimulation to environmental reflection and concept transfer—is one of the crucial points that received positive responses from validators. These stages are considered capable of representing the deep learning process, which not only focuses on mastering concepts but also on internalizing values, transferring knowledge to new contexts, and reflecting on ecological issues in the surrounding environment.

The implications of these findings show that a learning approach that combines *deep learning*, *Eco-STEAM*, and *edutainment* has high potential to strengthen 21st-century competencies, particularly *computational thinking*, science literacy, and ecological

responsibility from an early age. With its proven validity, this model can be an innovative alternative for elementary school science teachers in designing learning that is not only fun, but also meaningful and has a long-term impact on how students think and act.

However, this study has a number of limitations. First, the number of validators is still limited to three experts, so the perspectives of direct users—such as classroom teachers—have not been explicitly accommodated in this validation stage. Second, the validation carried out is conceptual and documentary in nature and has not been tested through actual field trials. Therefore, although the model is theoretically and design-wise valid, its actual effectiveness in improving students' science and *computational thinking* learning outcomes still requires further testing.

For further research, it is recommended that this model be tested in a real classroom context in elementary schools with diverse characteristics in terms of geography, facilities, and technological capabilities. In addition, the involvement of teachers as co-developers in the development of edutainment media and CT-based assessments will strengthen the practicality of the model. Testing the impact of the model on non-cognitive dimensions such as attitudes toward the environment, collaboration, and creativity is also an important aspect that can be explored in further studies.

Conclusion

Based on the results of validation by experts, the Eco-STEAM-integrated Edutainment Deep Learning learning model is declared valid and feasible for implementation in science learning in elementary schools. This model is considered capable of facilitating deep, contextual, and enjoyable learning through the integration of ecological approaches, technology, and interactive media that encourage active student engagement. The increase in validation scores from stage I to stage II shows that design improvements based on expert input have succeeded in improving syntax quality, content integration, and clarity of implementation. Going forward, it is recommended that this model be further tested in a real classroom context through limited trials and expanded by involving teachers as implementation partners, in order to assess its effectiveness in improving students' science comprehension, computational thinking skills, and environmental awareness more comprehensively.

Author Contributions

Conceptualization, M.Z. and S.A.; methodology, A.K.K.; software, A.K.K.; validation, M.Z., A.K.K., and N.F.; formal analysis, S.A.; investigation, A.M.; resources, S.A.; data curation, N.F.; writing—original draft preparation, M.Z.; writing—review and editing, A.K.K.; visualization, A.K.K.; supervision, S.A.; project administration, A.M.; funding acquisition, M.Z. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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