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Development and Validation of a Semiotic Project-Based Module to Support Early Childhood Numeracy Literacy

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ABSTRACT

Early Childhood Education (ECE) often relies on paper-based activities that limit children's engagement and contextual learning. To address this, a semiotic project-based module was developed to enhance early numeracy literacy through culturally relevant, hands-on learning aligned with children's developmental needs. This research employed a Research and Development (R&D) design using the 4D model (Define, Design, Develop, and Disseminate). Module development included needs analysis, diagnostic assessment, media and activity design, expert validation, small- and large-scale trials, and evaluation. The module integrated semiotic elements (icons, indices, and symbols) within project-based learning themed around traditional foods from Jember, Indonesia. Validity, practicality, and effectiveness were assessed through expert review, teacher questionnaires, and observational data. Expert validation results showed an average validity score of 85%, categorized as "very valid." Teacher responses in the small-scale trial (n=13) indicated 92.3% rated the module "very effective," while the large-scale trial (n=13) achieved 100% in the same category. Observations of children's participation indicated a 98% engagement rate, demonstrating high practical effectiveness. The findings suggest that the module is valid, practical, and effective in supporting early numeracy literacy. The use of semiotic representations within culturally contextualized projects provided meaningful numeracy experiences. However, the small sample size and local context limit generalizability. Further research with diverse populations and objective assessments is recommended.

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1. INTRODUCTION

Early Childhood Education (ECE) is a crucial foundation in shaping children's character, skills, and readiness for learning at the next educational level (Rahmi et al., 2024; Rumbidzai & Achebe, 2023). At this stage, children are in their golden age, which requires optimal stimulation through varied, contextual learning that aligns with their developmental stages (Jura & Naray, 2023; Nadlifah & Latif, 2024). However, in reality, the teaching modules used by some ECE teachers still rely heavily on paper-based learning. This reliance often makes learning activities less interactive and limits children's exploration of the real-world environment. Children tend to be directed to complete worksheets or written assignments, whereas the cognitive, language, motor, and socio-emotional development of young children is more effectively stimulated through direct experiences, play, and project-based activities (Plotnikova et al., 2025)

Teaching modules that place too much emphasis on a paper-based learning approach may overlook the potential for integrating technology, concrete media, and life-skill-based activities that align with the principles of ECE learning (Istiana & Widodo, 2023). This gap highlights the need for innovation in designing and selecting teaching modules that are more creative, interactive, and make use of active learning approaches (Borte et al., 2020; Carvalho et al., 2020). The development of teaching modules that combine the use of concrete media, digital tools, and direct experiences will help teachers create more meaningful, enjoyable learning that aligns with the characteristics of early childhood learners (Putri & Rofiah, 2025)

A semiotics-based project module is a learning module that integrates a project-based approach with semiotic theory, focusing on the analysis and understanding of signs, symbols, and meanings in real-world contexts through well-planned projects (Bolivar, 2023; Salmawati & Maryatun, 2024). In semiotics-based project learning, students do not only learn to understand concepts, but they also comprehend meanings by using symbols or signs and interpreting them to solve everyday problems through creative projects (Gulden, 2025; Suryaningrum et al., 2021). The semiotics-based project module for early childhood aims to utilize signs and symbols through activities that are appropriate to children's developmental stages. Signs, both visual and verbal, are used to represent abstract mathematical concepts to make them easier to understand (Suryaningrum et al, 2023; Supriadi et al., 2024). For young children, semiotics encompasses the understanding and interpretation of signs such as images, words, sounds, and body movements, according to the meanings perceived by each child (Chachlioutaki & Pantidos, 2024)

At an early age, children learn through observation, direct experience, and creative physical activities (Lugossy et al., 2021; Payne & Costas, 2020). Therefore, teachers must design teaching modules that engage children actively, creatively, and enjoyably according to their level of understanding. The semiotics-based project module provides opportunities for young children to explore the world through signs and symbols and to interpret them in order to develop communication skills, critical thinking, creativity, and the ability to collaborate with peers. Children's activities involving semiotics form the foundation for developing long-term skills in visual literacy, numeracy, and communication. (Chapman & O'Gorman, 2022; Karyono et al., 2025)

Early Childhood Education (ECE) institutions are expected to serve as accessible sources of literacy development (Forgie et al., 2022) for parents in need, as a tangible effort to counteract the loss of learning opportunities during the pandemic. They also play a role in strengthening early childhood literacy in building language and character skills, as well as contributing to the development of programs aligned with other local initiatives. One of the activities teachers can undertake is stimulating students to explore mathematics and think critically in solving mathematical problems contextually through numeracy skills (Kolar & Hodnik, 2021; Lestari et al., 2021)

Based on the result of the pilot study, teachers implemented paper-based learning. Teachers prepared several play activities from which students could choose; however, some of these activities were still paper-based. The use of paper-based learning was wasteful and costly, as it required frequent purchases of paper and ink for learning activities. This was attributed to teachers' lack of creativity in

developing engaging learning media for students. Teachers had not yet developed semiotics-based project modules.

The research question of the study is formulated as follows: how can semiotics-based project modules be developed and validated to improve early childhood numeracy literacy? The objective of this study is to produce a semiotics-based project module for early childhood that utilizes signs and symbols through project-based learning activities appropriate to children's developmental stages.

2. METHODS

This study employed a Research and Development (R&D) approach, which is a research methodology aimed at producing educational products and evaluating their effectiveness in the field of education (Indaryanti et al., 2025). The development of the module was based on the Thiagarajan model, commonly known as the 4D model, which includes four stages: Define, Design, Develop, and Disseminate (Hariyanto et al., 2022; Setiana & Peniati, 2023; Suryaningrum et al, 2023)

The research adopted and adapted these stages into the following steps:

1. Needs Analysis: Conducted by examining real classroom conditions to identify the need for mathematics teaching materials to be developed.
2. Diagnostic Assessment: Carried out to assess the numeracy literacy needs of early childhood learners.
3. Module Development: Involved the selection of appropriate media, determination of the module format, planning of learning stages, selection of developmentally appropriate play activities, and the overall product development.
4. Expert Validation: Conducted with a panel consisting of a language expert, an assessment expert, and an early childhood education specialist to ensure the module's academic and practical validity.
5. Implementation: The developed instructional module was tested in two stages: a small-scale trial involving 6 children and a large-scale trial involving 12 children to assess its practical applicability.
6. Evaluation: Conducted to measure the module's impact on students' learning outcomes and the quality of the learning process.

The data collection instruments used in this study included: (1) Needs Analysis and Diagnostic Assessment Instruments: These were employed to analyze the necessity for semiotic-based teaching materials and to identify the characteristics of early childhood learners. (2) Expert Validation Sheets: Used to collect data on the module's validity, assessed by a panel of three experts: a language expert, an assessment and instructional expert, and an early childhood education specialist. (3) Questionnaires: Distributed to respondents specifically, Kindergarten teacher at Jember to gather and record feedback on the developed product. The aim of the questionnaire was to determine the practicality level of the instructional module.

The data analysis technique utilized a Likert scale to assess and ensure that the developed instructional module met the criteria of validity, practicality, and effectiveness (Milenia et al., 2022). Expert validation was conducted to examine the validity of the developed semiotic project-based module. The expert validation instrument consisted of 20 items using a five-point Likert scale, covering content relevance, semiotic alignment, pedagogical suitability, and technical presentation. The following guidelines were used to evaluate the product's validity.

Table 1. Product Validity Categories

Validity Criteria	Validity Level
85.01% - 100%	Very Valid
70.01% - 85%	Valid
50.01% - 70%	Not Valid
1% - 50%	Very Not Valid

The practicality analysis was based on the results of teacher response questionnaires. The following is the guideline for analyzing product practicality using a Likert scale:

Table 2. Product Practicality Categories

Practicality Criteria	Level of Practicality
81% - 100%	Very Practical
61% - 80%	Practical
41% - 60%	Not Practical
1% - 40%	Very Not Practical

The effectiveness analysis of the teaching material was based on observations of early childhood behavior during participation in project-based learning. In this study, effectiveness is interpreted descriptively as children's observable engagement with early numeracy indicators during and after module implementation, rather than causal learning gains. The following is the guideline for analyzing learning completeness using a Likert scale:

Table 3. Categories of module effectiveness

Effectiveness Criteria	Category
81% - 100%	Very Effective
61% - 80%	Effective
41% - 60%	Not Effective
1% - 40%	Very Not Effective

Based on the effectiveness analysis above, the developed teaching material is considered effective if the students' learning outcomes meet at least the "Effective" category of mastery.

This study employed specific early childhood numeracy indicators to provide a clearer and more structured description of children's numeracy-related learning outcomes during the implementation of the semiotic project-based module. These indicators were used to describe observable numeracy behaviors demonstrated by children in learning activities, rather than to measure learning gains in a causal or experimental sense. The selected indicators represent fundamental domains of early numeracy literacy, including counting, quantity comparison, pattern recognition, measurement concepts, and classification. A summary of the numeracy indicators used in this study is presented in Table 4

Table 4. Early Childhood Numeracy Indicators Assessed

Indicator	Description
Counting	Counting objects from 1–10
Comparing quantity	Identifying more/less
Pattern recognition	Identifying simple repeating patterns
Measurement concepts	Using terms long–short, big–small
Classification	Grouping objects by shape/size

3. FINDINGS AND DISCUSSION

The development of the semiotic project-based module was carried out through six main stages: (1) needs analysis, (2) diagnostic assessment, (3) product development, (4) expert validation, (5) implementation, and (6) evaluation. Each stage is described in detail below

3.1. Needs Analysis

This stage was conducted by examining field conditions to identify the necessity for developing mathematics teaching materials. The goal was to determine to what extent semiotic-based learning could stimulate early childhood learners to understand mathematical concepts more meaningfully. The needs analysis revealed the following findings:

a. Young children require concrete and contextual learning media, which is consistent with Piaget's theory stating that children in early childhood are still in the preoperational stage (Nabilah et al., 2024)
b. Children need various forms of representation, including visual, concrete, verbal, and symbolic. This aligns with (Kampeza & Pedregosa, 2024; Suryaningrum et al., 2020) who emphasizes that

these representations are interconnected with children's everyday activities. To support symbolic representation, semiotics—through signs such as icons (images), indices (clues), and symbols (numbers or abstract signs)—can meet the developmental needs of early learners (Suryaningrum & Lestari, 2022)

c. Semiotic-based learning helps children grasp mathematical concepts through contextual approaches, making abstract ideas more accessible (Testa et al., 2022)
d. Teaching materials integrated with semiotics can transform abstract mathematics into concrete or visual concepts, thereby helping children relate mathematics to their real-life experiences (Suryaningrum & Ningtyas, 2019; Wei et al., 2024)

3.2. Diagnostic Assessment

This stage was conducted to examine the numeracy literacy needs of early childhood learners. The diagnostic assessment produced the following findings:

a. Young children exhibit varying levels of understanding, influenced by experiences gained through parental stimulation at home, play activities, and interactions with their environment (Kaya et al., 2025)
b. Children develop at different rates. Some are still in the stage of recognizing basic shapes and numbers, while others are already capable of counting, understanding patterns, quantities, measurement, and comparison (Junker et al., 2024)
c. Children grasp mathematical concepts more easily through comparative vocabulary, such as "more or less," "bigger or smaller," and "farther or closer." This suggests that early learners benefit from play-based activities that integrate numeracy with language development and games that stimulate logic and mathematical thinking (Miftahurrohmah & Hasibuan, 2024)
d. Mathematics learning for early childhood requires a holistic approach, offering concrete, contextual, interactive, and enjoyable numeracy experiences tailored to their developmental stage. In mathematics learning, literacy plays a key role due to the need for children to understand terms, symbols, and signs used to communicate mathematical ideas and to solve problems (Kusmaryono et al., 2024)

3.3. Development of the Semiotic Project-Based Module

The development of the semiotic project-based module involved several key steps: (a) selection of media and module format, (b) planning of learning stages, (c) selection of play activities, and (d) product development. Each of these steps is described in detail below:

a. Media Selection and module format,

The media were selected based on the developmental level and interests of early childhood learners. The chosen media included images of traditional foods from the city of Jember. To make the learning experience more enjoyable and to capture children's attention and motivation, the researchers incorporated short videos exploring various traditional foods from Jember (Ningsi & Hartono, 2025). These videos also demonstrated how the foods are prepared. The module used images of these traditional dishes as icons representing the city's cultural identity.

b. Planning the Learning Stages

The learning activities were designed in three stages: Introduction: Children were introduced to traditional foods from Jember. Development: Children participated in making the traditional foods. Conclusion: Children shared their experiences and showcased their culinary creations in a mini exhibition.

c. Selection of Play Activities

The play activities were carefully chosen to suit the age and characteristics of the children. The researchers designed four main food-making activities: *suwar-suwir* (a traditional sweet), *prol tape* (cassava cake), edamame milk, and edamame pudding.

d. Product Development

The learning objectives within the semiotic project-based module were aligned with three dimensions of the Pancasila Student Profile: Global Diversity. The goal at this stage is for children to recognize their identity and cultural practices within the family. Collaboration: The expected outcome is for children to become accustomed to working cooperatively in group settings. Creativity: Children are encouraged to explore and express their thoughts and/or feelings through simple creative works and actions, and to appreciate the works and efforts of others.

An overview of the semiotic project-based module development is presented in Figure 1 below.

Figure 1. Initial Design of the Semiotic Project Based Module

3.4. Expert Validation

Expert validation was conducted by a panel consisting of a language expert, an assessment expert, and an early childhood education expert. The validation team members were selected based on their expertise relevant to the research and development objectives of this study. The validation was carried out by three validators: two faculty members from Universitas Muhammadiyah Jember, who served as experts in instructional design and assessment, and one early childhood education expert, a teacher from TK ABA 3 Jember. The validation was carried out by three validators with relevant expertise in early childhood education. The results of the expert validation are presented in Table 4 below:

Table 5. Expert Validation Results

No	Component	Total Scor	Percentage	Criteria
1.	Profile and Objectives	38	95%	Very Valid
2.	Assessment Rubric	32	80%	Valid
3.	Learning Activities	40	100%	Very Valid
4.	Assessment	36	90%	Very Valid
5.	Language	32	80%	Valid

Based on Table 4, the results indicate that the developed product is highly valid in terms of profile and objectives, learning activities, and assessment, with percentages equal to or exceeding 90%. It is also considered valid in terms of the assessment rubric and language, each with a percentage of 80%. Based on the evaluations provided by the three experts, it can be concluded that the semiotic project-based module developed in this study is feasible for use in early childhood education. Additionally, feedback from the assessment and language experts emphasized that the module should further highlight its semiotic components, as it is designed and positioned as a semiotic-based project module.

3.5. Product Improvement

The product improvement was made based on feedback from assessment and learning experts. Based on the feedback, the following improvements were implemented: (1) the semiotic-based project module was enhanced by adding images of typical dishes from Jember, with embedded links to videos showing their preparation process, (2) images of the tools and measuring instruments required for preparing these dishes were included, (3) several examples of packaging that can be used were added, (4) a depiction of the market day event to be conducted was included. The revised version of the semiotic-based project module can be seen in Figure 2.

Figure 2. Final Version of the Semiotic Project- Based Module

3.6. The implementation

The implementation of the teaching module that has been designed and developed in accordance with the standards will undergo product trials conducted in two stages: a small-scale trial and a large-scale trial. The small-scale trial will be conducted with six children aged 5–6 years, while the large-scale trial will involve twelve children aged 5–6 years. In the small-scale trial, six children participated in the learning activities, while 13 teachers completed the practicality questionnaire based on classroom observation and module usability. In the small-scale trial, the entire project-based learning activity will be carried out indoors, including watching a video about traditional food from Jember City, watching a video on how to make the traditional food, making the traditional food, packaging the food, and exhibiting it. The practicality analysis is based on the results of a questionnaire completed by 13 kindergarten teachers after implementing the small-scale trial, with the data obtained as follows.

Table 6. Small-Scale Trial Effectiveness

No	Criteria	Frequency	Percentage
1	Verry Effective	12	92.3%
2	Effective	1	7.7%
3	Ineffective	0	0%

The table above shows that the teaching module was declared highly effective at 92.3% and effective at 7.7%. Therefore, based on the results of the small-scale trial, the semiotic-based project module is very practical for improving early childhood numeracy literacy. After conducting the small-scale trial, the research team and teachers conducted a reflection. The results of the reflection were that children did not choose the ingredients used, and preparing food indoors resulted in mixed odors, limited visibility, and smoke that could not be immediately released. Based on these reflections, the research team and teachers implemented a follow-up plan: before preparing typical Jember dishes, children selected the ingredients used. Preparation of food was carried out outdoors so that cooking odors did not mix, provided a wide view, and smoke could be immediately dispersed (Sun & Singer,

2023). The large-scale trial involved 12 children, and 13 teachers completed the practicality questionnaire based on classroom observation and module usability. The results of the large-scale trial yielded the following data:

Table 7. Teacher Response Frequency

No	Criteria	Frequency	Percentage
1	Verry Effective	13	100%
2	Effective	0	0%
3	Ineffective	0	0%

The table above shows that the teaching module was 100% highly effective. Therefore, based on the results of the large-scale trial, the semiotic-based project module was highly effective in improving numeracy literacy in early childhood. The results of both small- and large-scale trials indicate that the semiotic-based project module is a highly effective product.

3.7. Evaluation

An evaluation was conducted to determine the impact on students' learning outcomes and the quality of teaching. From the observation of project-based learning using the semiotic module, an analysis of the effectiveness of the teaching materials was conducted, based on observations of the behavior of early childhood students. It was found that 98% of the children participated enthusiastically in the project-based learning. The children followed the project learning sequence, starting with watching videos about typical dishes from Jember, discussing what they had seen in the video, selecting ingredients for making the Jember dishes, measuring the ingredients according to the video instructions, collaborating with friends to prepare the dishes, and packaging the food. This demonstrates that the semiotic-based project module is highly effective for use in early childhood education.

The development of a semiotics-based project module produced high levels of engagement and effectiveness. Three main mechanisms support these research findings:

1. Developmental alignment (Piaget/Vygotsky/Bruner). Project activities involving manipulatives and cultural artifacts situate numeracy within concrete and social experiences, consistent with the preoperational stage that requires hands on experiences and language scaffolding (Subeini, 2021). Semiotic elements including pictures, labels, number symbols, and gestures serve as tools for joint attention and scaffolding within the Zone of Proximal Development (ZPD), supporting the internalization of early mathematical concepts.

   The semiotic framework underpinning this module involves three core types of signs icons, indices, and symbols (Peirce, 1931). In the learning process, icons (e.g., pictures or models of traditional foods) serve as direct visual representations that help children recognize objects and relate them to real-world experiences. Indices (e.g., smoke from cooking, ingredients, or contextual cues) function as indicators linking observed phenomena to meaning, guiding children's reasoning about cause and effect. Symbols (e.g., numbers, labels, or measurement marks) represent abstract ideas such as quantity or proportion. By navigating across these three types of signs, children gradually move from perceptual understanding to conceptual abstraction, thus facilitating the internalization of numeracy concepts in a playful and meaningful way.
2. Shifts across semiotic representations. Children moved from visual to verbal to symbolic representations. (Pantaleo, 2023; Thomas, 2024). Based on the study's observations, students progressed from watching videos of local foods, selecting ingredients, measuring, packaging, and exhibiting project outcome reflecting these cross representation shifts. This process engaged students actively in project-based learning, with a recorded participation rate of 98%.
3. Culturally grounded Project-Based Learning (PjBL). Incorporating local cultural contexts enhances early childhood engagement because children connect directly with meaningful real-world experiences (Anderson et al., 2022; Yang, 2022)

The limitations of this study should be acknowledged to provide context for interpreting the findings. The relatively small sample size, consisting of only six and twelve children, was sufficient for formative research and development but does not allow for strong inferential claims. Furthermore, the activities were designed specifically around the culinary culture of Jember, and thus their applicability to other regional or socio-cultural contexts, including urban–rural variations, has yet to be tested. The short duration of the trial, limited to two brief cycles, also constrains the conclusions that can be drawn regarding the durability of learning outcomes, the long-term adoption of the approach by teachers, and its potential impact in the home environment. In addition, the instruments employed to measure effectiveness relied primarily on expert validation, teacher questionnaires, and observational data on children's participation. While useful, these measures did not include standardized numeracy assessments or detailed analyses of children's speech and gestures, thereby limiting the precision and depth of the data obtained. Although the findings of this study demonstrated the effectiveness, validity, and practicality of the semiotic project-based module, it is important to note that these results cannot yet be generalized to a broader population due to the limited sample size and localized cultural context. Further large-scale studies involving diverse early childhood settings across different regions and socio-economic backgrounds are necessary to confirm the module's broader applicability and reliability.

In light of the limitations identified in this study, several directions for future research are suggested. Subsequent studies should consider involving a larger and more diverse sample of participants to provide a stronger foundation for inferential claims and more robust statistical analyses. In addition, it is important to extend the research to different geographical, social, and cultural contexts, including both urban and rural settings, as well as incorporating diverse local cultural themes, in order to broaden the generalizability and demonstrate the adaptability of the module. Future research would also benefit from a longer implementation period so as to examine the consistency of children's learning outcomes, the sustainability of teacher adoption, and the potential indirect impact within the home or community environment. Furthermore, the use of more objective and comprehensive measurement instruments is highly recommended. Employing standardized numeracy tests, analyzing children's speech and gestures through both qualitative and quantitative approaches, and triangulating findings with parental input would significantly enhance the validity and reliability of the data. Future research should also prioritize the development of more objective and standardized numeracy measurement instruments. The current study relied on teacher observations and expert validation, which, while informative, may be subject to subjective interpretation. Constructing validated tools that quantitatively assess children's numeracy progress such as standardized performance-based assessments would enhance both the accuracy and comparability of future studies in early childhood numeracy literacy.

4. CONCLUSION

The study addressed the overreliance on paper-based learning in early childhood education, which limits children's active engagement and contextual learning. It developed and tested a semiotics-based project module, integrating signs, symbols, and culturally relevant activities to teach early numeracy through hands-on, collaborative projects. Expert validation, teacher feedback, and classroom trials demonstrated high validity, practicality, and effectiveness, with children showing strong participation and enthusiasm. For early childhood education teachers and policymakers, adopting such context-rich, semiotic project modules can foster deeper numeracy understanding, improve engagement, and serve as a scalable alternative to conventional worksheet-based approaches.

While the semiotic project-based module has proven to be a promising approach for enhancing early numeracy literacy, its generalizability remains limited and necessitates broader empirical validation. Moreover, the development of more objective numeracy instruments and further elaboration on semiotic representations, particularly the interplay between icons, indices, and symbols, will contribute significantly to future advancements in early childhood educational research.

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