Jurnal Ilmiah Profesi Pendidikan
Volume 11, Nomor 1, Februari 2026
ISSN (Print): 2502-7069; ISSN (*Online*): 2620-8326

Optimizing Inclusive Education Through Interactive Learning Modules for Children with Special Needs in Early Childhood: Implications for SDG 4.5

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Article History
Received : December 22th, 2025
Revised : January 20th, 2026
Accepted : February 06th, 2026

Abstract: This study evaluates the development of an interactive learning module aimed at optimizing inclusive education for children with special needs in early childhood education (ECE), in support of Sustainable Development Goal (SDG) 4.5. Employing a Research and Development (R&D) approach with the 4D model (Define, Design, Develop, Disseminate), data were collected through curriculum analysis, classroom observations, interviews with teachers and parents, expert validation, teacher practicality questionnaires, and child engagement rubrics, and then analyzed descriptively. The findings indicate that the module was rated "highly valid" by experts with an average score of 89.7%, and "highly practical" by teachers with an average score of 87.5%. Children's engagement showed a significant increase, rising from 52.8% before to 80.6% after the use of the module, with the greatest improvement observed in social interaction (+29%). These results demonstrate that the UDL-based interactive module is effective in enhancing inclusivity, children's participation, and teachers' confidence in inclusive ECE classrooms, thereby contributing to the achievement of SDG 4.5.

Keywords: Inclusive education, Early childhood, Interactive learning, SDG 4.5

INTRODUCTION

Inclusive education has become a global priority, particularly within the framework of Sustainable Development Goal (SDG) 4.5, which emphasizes eliminating disparities in education and ensuring equal access to quality learning opportunities for vulnerable groups, including children with disabilities. Early Childhood Education (ECE) plays a pivotal role in this agenda, serving as the foundation for lifelong learning, social integration, and personal development (UNESCO, 2020). Nevertheless, despite various international efforts, inclusive practices in ECE remain fragmented and often lack evidence-based learning resources specifically designed to meet the diverse needs of children with special needs.

In Indonesia, although inclusive policies have been adopted, their implementation in ECE still faces significant challenges. Data from the World Bank (2020) reveal that only 19.5% of inclusive schools serve children aged 4–6 years, and merely 13% of teachers have received training in inclusive education. Furthermore, ECE is not yet part of compulsory education, which limits budget allocations to only about 4.5% of the Ministry of Education and Culture's total expenditure (World Bank, 2020). This situation results in persistent gaps in both access and quality of education for children with special needs at the early childhood level.

Children with special needs in ECE frequently encounter barriers in accessing fair and engaging learning experiences. Conventional teaching materials often fail to accommodate their unique cognitive, emotional, and sensory profiles, leading to low participation and limited developmental outcomes (Sharma & Loreman, 2021). Within this context, the integration of interactive learning modules is increasingly recognized as a promising pedagogical strategy. Such modules can combine multimedia elements, adaptive activities, and interactive features that foster engagement, accessibility, and individualized learning pathways (Anderson & Craig, 2019).

Previous studies have demonstrated the potential of interactive modules to enhance learning motivation and participation among children with disabilities (Kurniawati et al., 2022; Rahman et al., 2023). However, most of these studies have focused on primary or secondary education, with relatively few addressing the

context of ECE—despite this stage being the most critical period for developing foundational skills and inclusive practices. Moreover, existing interventions are often not supported by systematic development processes or rigorous evaluations, limiting their scalability and policy impact (Al-Azawei, Serenelli, & Lundqvist, 2017).

This study seeks to address these gaps by developing and evaluating an interactive learning module specifically designed for children with special needs in ECE. The study adopts the 4D model (Define, Design, Develop, and Disseminate) to ensure that the development process is systematic and iterative (Thiagarajan, Semmel, & Semmel, 1974; Sugiyono, 2019). The innovation of this research lies in optimizing inclusive education practices through the integration of pedagogically and technologically enriched learning resources, validated by experts, and tested directly in real classroom environments.

The significance of this research is twofold. First, it provides empirical evidence on how interactive learning modules can enhance inclusivity and engagement within ECE settings. Second, it contributes to achieving SDG 4.5 by offering practical solutions that can be scaled up to reduce educational disparities for children with special needs. By bridging theory and practice, this study is expected to inform policymakers, educators, and researchers in developing effective strategies for realizing inclusive, equitable, and high-quality education from the earliest stages of learning.

METHODS

This study employed a Research and Development (R&D) approach using the 4D model (Define, Design, Develop, and Disseminate) developed by Thiagarajan, Semmel, and Semmel (1974). The model has been widely applied in the development of instructional materials and contemporary learning media (Indaryanti et al., 2024; Ansori et al., 2024; Syam & Furwana, 2022). The selection of this model was based on its systematic procedures, which enable the development of an interactive learning module specifically designed for young children with special needs to promote inclusive education in alignment with SDG 4.5.

1. Define

The initial stage aimed to identify the learning needs of children with special needs in inclusive early childhood education. Activities included curriculum analysis, reviewing relevant learning outcomes, and identifying challenges through interviews with teachers, parents, and special education experts. In addition, classroom observations were conducted to obtain contextual data on learning barriers and strategies already implemented. The collected data were analyzed qualitatively to produce a needs map, which was then used to formulate objectives, content characteristics, and specifications for an interactive learning module tailored to the characteristics of children with special needs and the principles of inclusive education.

2. Design

At this stage, a prototype of the interactive learning module was designed by integrating inclusive learning principles and interactive features appropriate for young children with special needs. The design process involved preparing a storyboard, selecting media elements (visuals, audio, and interactive activities), and developing evaluation instruments such as expert validation sheets, teacher practicality questionnaires, and child engagement rubrics. Pedagogical aspects were also considered, including differentiated instruction, the use of simple and communicative language, and a child-friendly interface design accommodating specific limitations. The Universal Design for Learning (UDL) principles served as the foundation, ensuring that the module could be accessed by various categories of children with special needs, including those with cognitive, language, and motor impairments. The design stage produced an initial prototype draft ready for expert validation before proceeding to the development phase.

3. Develop

The development stage involved producing the initial prototype of the module, followed by expert validation to assess content accuracy, pedagogical suitability, and technical quality. Validation was conducted by subject matter experts, media specialists, and inclusive education practitioners to ensure the module's relevance for children with special needs and alignment with early childhood learning principles. Revisions were made based on expert feedback so that the prototype became more representative and feasible for use. Subsequently, the module was tested on a small scale in an

inclusive ECE setting to assess feasibility, practicality, and initial responses from teachers and children. The pilot test also examined child engagement, ease of use, and the potential for enhancing learning interactions. Data collected from the trial were analyzed descriptively and qualitatively, then used for further refinement, resulting in an interactive module that was valid, practical, and ready for broader implementation.

4. Disseminate

The final stage consisted of implementing the module on a larger scale across several inclusive ECE institutions to comprehensively evaluate its applicability. This implementation aimed to assess the module's effectiveness in improving child engagement, supporting learning achievement, and strengthening teachers' capacity in inclusive teaching practices. Data collection involved classroom observations, interviews with educators and parents, as well as questionnaires to evaluate user perceptions and satisfaction. The evaluation results served as the basis for refining the module before recommending it as an innovative learning resource that could be replicated in other educational institutions. Dissemination was also carried out through academic publications in international peer-reviewed journals, presentations at national and international seminars, and distribution of the module to partner schools as a tangible contribution to achieving SDG 4.5 on inclusive, equitable, and quality education for all children.

FINDINGS AND DISCUSSION

Based on the research procedure adapted from the 4D model (Define, Design, Develop, and Disseminate), the results of this study are presented in accordance with the stages that were carried out. The presentation not only outlines the empirical findings from each stage but also discusses them comparatively with previous studies to strengthen academic validity. The following section systematically presents the analysis and development outcomes across the Define, Design, and Develop stages, leading to the Disseminate stage as the implementation of the interactive learning module for young children with special needs in early childhood education settings, in support of inclusive education and the achievement of SDG 4.5.

1. Define

The needs analysis revealed that young children with special needs in inclusive classrooms face significant disparities in accessing equitable learning experiences. Classroom observations indicated low levels of engagement, particularly during text-based and verbally instructed activities. Both teachers and parents emphasized that conventional learning materials fail to accommodate children's cognitive, emotional, and sensory profiles, resulting in limited participation and restricted developmental outcomes. These findings highlight the importance of implementing differentiated instruction and adaptive instructional design tailored to the diverse needs of learners. This aligns with Sharma and Loreman (2021), who argue that the primary barriers to inclusive education lie in the limited availability of child-friendly media and strategies for children with special needs. Similarly, Majoko (2020) stressed that without adaptive learning resources, inclusive classrooms risk becoming spaces of passive presence rather than active participation. Furthermore, Florian and Black-Hawkins (2023) emphasized that inclusive pedagogy can only be realized when teachers adopt flexible, responsive, and child-centered learning strategies. In addition, Rao and Mehta (2022) demonstrated that multimodal learning strategies significantly enhance engagement, social interaction, and the acquisition of basic concepts among young children with special needs.

These findings are also consistent with Brown et al. (2023), who highlighted the effectiveness of gamification-based interactive modules in enhancing motivation and focus among children with developmental challenges. Likewise, Kozma (2021) showed that integrating interactive technology can expand educational accessibility for vulnerable groups by providing equitable and meaningful learning experiences. Thus, the Define stage underscores the urgent need for adaptive, interactive, and multimodal learning media in inclusive classrooms to bridge gaps in access, increase engagement, and promote active participation among children with special needs from an early age. This forms a crucial foundation for developing the interactive learning module designed in this study.

2. Design

The design stage produced a prototype grounded in the principles of Universal Design for Learning (UDL), integrating visual, auditory,

and interactive elements to support multisensory engagement. The module was designed with accessibility in mind, including the use of simple language, easily recognizable icons, high - contrast colors to aid children with visual impairments, and child-friendly navigation for those with motor or cognitive limitations. Moreover, the module accommodates visual, auditory, and kinesthetic learning styles through a combination of digital media, interactive games, and hands-on activities. Evaluation instruments - including expert validation sheets, teacher practicality questionnaires, and child engagement rubrics - were developed to ensure that the final product met the criteria of validity, practicality, and effectiveness. This step is particularly important, as engagement in inclusive classrooms extends beyond attendance to encompass active participation in learning processes (Florian & Black-Hawkins, 2023).

These findings are consistent with Al-Azawei et al. (2017), who emphasized that UDL-based media can significantly broaden learning accessibility for vulnerable groups. Similarly, Rao et al. (2019) demonstrated that integrating UDL principles provides flexibility in content delivery, modes of engagement, and forms of assessment, offering multiple entry points for children with special needs. Smith et al. (2022) also confirmed that UDL-based instructional design enhances motivation, collaboration, and self-confidence among children with special needs in inclusive settings. Furthermore, Edyburn (2020) reminded us that UDL is not merely a technical approach but a pedagogical framework requiring teachers to design learning with learner diversity in mind from the outset. Courey et al. (2013), in their study of early childhood education, found that UDL-based instruction reduces learning barriers, improves lesson planning, and fosters greater independence among young learners. More recently, Katz and Sokal (2022) stressed that UDL supports systemic cultural change toward deeper inclusion by empowering teachers with greater confidence and competence to adapt instruction for all learners.

Accordingly, the Design stage in this study not only produced an interactive module prototype but also established a conceptual foundation for implementing inclusive education that is equitable, responsive, and oriented toward active participation. This aligns with the global agenda of SDG 4.5, which calls for the elimination of disparities in education through innovative, fair, and inclusive learning media.

3. Develop

At the Develop stage, the interactive learning module prototype created during the design phase was validated by three experts: an early childhood education specialist, a special education expert, and an instructional design specialist. Validation results indicated that the module received an average score of 89.7%, placing it in the “highly valid” category. The aspects evaluated included content relevance, clarity of language, visual appeal, interactivity, and alignment with the principles of Universal Design for Learning (UDL).

Table 1. Expert Validation Results of the Interactive Learning Module

Aspect	Indicator	Validator 1	Validator 2	Validator 3	Average (%)	Category
Content Validity	Alignment of material with inclusive learning objectives; integration with the early childhood curriculum	90	92	88	90.0	Highly Valid
Language	Clarity, simplicity, and appropriateness of language for children with special needs	88	87	90	88.3	Highly Valid
Design/Visual	Attractiveness of layout, use of icons, color contrast, and accessibility features	92	89	91	90.7	Highly Valid
Interactivity	Level of engagement through activities; support for multimodal learning (visual, auditory, kinesthetic)	89	90	88	89.0	Highly Valid
Instructional Strategy	Flexibility, differentiation, and alignment with UDL principles	91	93	90	91.3	Highly Valid
Overall Average					**89.7**	**Highly Valid**

Based on Table 1, the instructional strategy aspect received the highest score (91.3%). This indicates that the developed interactive module is well-aligned with the principles of Universal Design for Learning (UDL), which emphasize the importance of providing multiple alternatives in presenting content, engaging learners, and assessing learning outcomes (Meyer et al., 2014). An adaptive module that incorporates instructional differentiation enables children with special needs to access learning more equitably, not only in academic domains but also in social and emotional development.

The design/visual aspect, which scored highly at 90.7%, highlights that the use of icons, high-contrast colors, and child-friendly layouts significantly contributed to improved engagement. Dalton et al. (2021) emphasized that inclusive visual design can reduce cognitive barriers while supporting children with limited attention spans. Similarly, CAST (2018) asserted that visual accessibility is a key prerequisite of UDL in promoting multisensory engagement.

Language received the lowest score (88.3%), though it still fell within the "highly valid" category. This suggests that further simplification of vocabulary and instructions could make the module more developmentally appropriate for young children. Snow and Matthews (2016) found that simple language, repetition, and visual supports improve comprehension among children with communication challenges. Likewise, González-Gil et al. (2020) stressed the importance of aligning instructional language with the developmental context of children with special needs to ensure more meaningful learning.

In terms of interactivity (89.0%), validation results confirmed that the module successfully provided multisensory learning activities (visual, auditory, and kinesthetic). This finding aligns with Ok and Rao (2019), who demonstrated that multimodal strategies enhance opportunities for active participation among children with special needs in inclusive settings. The module's interactive features also reinforce the findings of Brown et al. (2023), who highlighted the effectiveness of gamification in improving motivation and engagement in inclusive classrooms. Overall, the validation results demonstrate that this interactive module is highly feasible and ready for further trials. The consistently high ratings across all aspects indicate that the module not only meets content and design standards but also aligns with inclusive pedagogical principles. This reinforces the perspectives of Al-Azawei et al. (2017) and Katz & Sokal (2022), who argue that integrating UDL into learning media broadens access, enhances learning experiences, and strengthens teacher confidence in managing inclusive classrooms.

Thus, the Develop stage shows that the product has a strong theoretical and empirical foundation. The module is expected to serve as a viable solution for optimizing inclusive education in early childhood settings, while also contributing to the achievement of SDG 4.5 by ensuring equitable access to education for all children, including those with special needs.

4. Disseminate

At the Disseminate stage, the validated interactive learning module was piloted on a limited scale in three inclusive early childhood education centers. The trial involved 12 teachers and 25 children with special needs (aged 4 - 6 years) with diverse challenges, including cognitive, communication, and fine motor difficulties. The trial was conducted over four weeks within daily thematic learning activities. Teachers were given a brief orientation on how to use the module, while the researchers provided support to ensure implementation was consistent with the design. Data were collected through teacher practicality questionnaires, child engagement observation sheets, and field notes. This approach was chosen to capture not only the practicality of the module from the teachers' perspective but also its effectiveness in enhancing children's participation in learning. Thus, this stage served as a practical verification of the development outcomes from earlier phases while also assessing the potential for implementing the module in various inclusive early childhood contexts.

Table 2. Teacher Practicality Test Results of the Interactive Learning Module

Aspect	Indicator	Average Score (%)	Category
Clarity of Instructions	Ease of understanding the module's usage guidelines	88.0	Highly Practical
Ease of Implementation	Ease of integrating the module into classroom activities	87.5	Highly Practical
Flexibility	Ability of the module to be adapted to various child needs	86.5	Highly Practical
Attractiveness	Teachers' assessment of children's interest in the module	88.0	Highly Practical
Overall Average		**87.5**	**Highly Practical**

The results in Table 2 show that teachers rated the module as highly practical, with an overall average score of 87.5%. Teachers emphasized that the module was easy to adapt to classroom conditions and children's individual profiles, while also enhancing learning motivation. In addition, teachers reported that the module facilitated the process of differentiated instruction by providing alternative activities tailored to each child's abilities. The module was considered not only to enrich teaching methods but also to reduce teachers' workload in preparing supplementary materials, making it more efficient for daily classroom routines.

These findings are consistent with Edyburn (2020), who stated that Universal Design for Learning (UDL)-based media increases teachers' flexibility in adapting instructional strategies to students' needs. Furthermore, Katz and Sokal (2022) highlighted that the availability of practical and adaptive learning tools empowers teachers with greater confidence in implementing inclusive education. Therefore, the high practicality score of the module in this study indicates that the product developed is not only feasible but also relevant to supporting inclusive practices in the field.

Table 3. Results of Children's Engagement in Learning

Child Engagement Indicator	Before Module (%)	After Module (%)	Improvement (%)
Attention during activities	56.0	82.5	+26.5
Active participation	52.0	80.0	+28.0
Social interaction	48.0	77.0	+29.0
Response to instructions	55.0	83.0	+28.0
Overall Average	52.8	80.6	+27.8

Based on Table 3, there was a significant increase in children's engagement, rising from an average of 52.8% before using the module to 80.6% after its implementation. The largest improvement was observed in social interaction (+29.0%), indicating that the module not only supports cognitive development but also plays a crucial role in helping children build social relationships in an inclusive classroom. This demonstrates that using an interactive module can create a more collaborative learning environment, where children are more encouraged to participate, share experiences, and actively respond to teacher instructions. In addition to social interaction, significant improvements were also seen in attention, active participation, and response to instructions, each increasing by more than 25%. This shows that interactive modules based on the Universal Design for Learning (UDL) consistently enhance children's multisensory engagement, enabling them to learn through multiple representation pathways.

These findings align with Ok & Rao (2019), who emphasized that multimodal learning strategies effectively increase participation among children with developmental challenges in inclusive settings. Similarly, Brown et al. (2023) demonstrated that interactive elements and gamification can boost motivation and social engagement in early childhood. Furthermore, Florian & Black-Hawkins (2023) highlighted that social engagement is a key indicator of success in inclusive education, as it allows children with special needs to feel part of the learning community. The following graph presents the analysis of children's engagement before and after using the interactive learning module. It clearly shows a significant increase across all engagement indicators (attention, active participation, social interaction, and response to instructions).

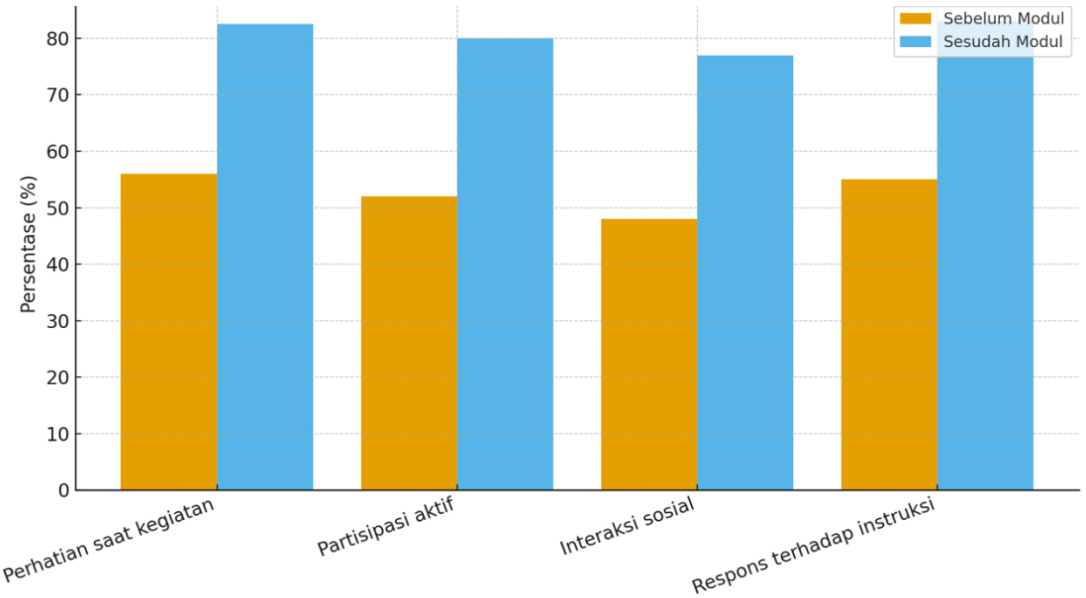

Figure 1. Graph Comparing Children's Engagement Before and After Using the Module

The results of the Disseminate stage indicate that the UDL-based interactive learning module was rated as highly practical by teachers and effective in enhancing the engagement of children with special needs in early childhood education (PAUD). Teachers' evaluations align with the findings of Katz & Sokal (2022), who emphasized that UDL provides a framework that enables teachers to tailor instructional strategies to the diverse needs of children. The significant increase in children's engagement is consistent with the study by Ok & Rao (2019), which demonstrated that multimodal media strengthen attention and participation among children with developmental challenges. Additionally, this study reinforces the findings of Brown et al. (2023), highlighting the effectiveness of gamification and digital interactivity in boosting motivation and collaboration in inclusive classrooms.

From an inclusive education perspective, these results confirm that the interactive module functions not only as a learning tool but also as a pedagogical instrument to reduce gaps in educational access. This aligns with Sharma & Loreman (2021), who argued that one of the major barriers to implementing inclusive education is the lack of learning media that are accessible to children with special needs. The module developed in this study effectively addresses these barriers through instructional differentiation, flexible content, and multisensory support. Furthermore, Florian & Black-Hawkins (2023) emphasized that effective inclusive education not only prioritizes access but also fosters active participation for every child. The findings of this study support this perspective, as the interactive module was shown to enhance children's social interaction, helping them feel part of the learning community. This is crucial because true inclusion is not merely about a child's presence in the classroom, but about their meaningful engagement in learning activities.

Thus, the Disseminate stage demonstrates that the developed product is not only valid and practical but also has a tangible positive impact on the cognitive, social, and emotional engagement of children with special needs in inclusive classrooms. These results reinforce the study's contribution to achieving SDG 4.5, which aims to ensure equitable access to education, improve the quality of learning experiences, and eliminate disparities for children with special needs from an early age.

CONCLUSION

This study was conducted to address a critical gap in early childhood inclusive education through the development of an interactive learning module specifically designed for children with special needs. Using the 4D model, the research successfully achieved its primary objectives: designing, validating, and disseminating a pedagogically grounded learning resource enriched with technology to promote equitable participation in inclusive classrooms. The findings confirm that integrating the

principles of Universal Design for Learning (UDL) into early childhood learning modules provides multiple pathways for engagement, representation, and expression for children with diverse needs. This integration not only facilitates the learning process but also reduces barriers that have traditionally limited participation in inclusive learning contexts. As a scientific contribution, this study demonstrates that systematically developed interactive modules can serve as replicable models to advance inclusive education practices while accelerating progress toward SDG 4.5. Accordingly, the research underscores the importance of adaptive, multisensory, and teacher-friendly learning resources in ensuring that inclusive education not only guarantees access but also provides meaningful participation and holistic development for all children.

Future research is recommended to implement the module on a larger scale and over a longer period to assess the sustained impact of the interactive module on the development of children with special needs. The integration of advanced technologies, such as augmented reality (AR) and artificial intelligence (AI), also has the potential to enrich learning experiences, making them more personalized and immersive. Furthermore, strengthening teacher capacity should be a key focus, as the successful implementation of the module heavily depends on educators' readiness and skills in adapting UDL principles. Nonetheless, this study has certain limitations, including a small sample size, a relatively short trial period, and variations in school infrastructure and parental involvement.

ACKNOWLEDGMENT

The author expresses sincere gratitude to the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia for the support provided through the research grant scheme. Thank are also extended to the early childhood education institutions, teachers, and parents who dedicated their time and contributed valuable input to this study.

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