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Smart Farming Project-Based Learning as a Socio-Material Learning Space in Rural Special Education Schools

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Abstract

This study aims to analyze the implementation of smart farming based on Project-Based Learning (PjBL) as a socio-material learning space that mediates student participation, agency, and engagement in special education within rural contexts. The study was conducted at SLB Muhammadiyah Kutoarjo, a special education school (*Sekolah Luar Biasa*) located in rural Central Java, Indonesia and involved 35 students aged 7–12 years who have intellectual disabilities and autism spectrum disorder, as well as four special education teachers. The study employed a convergent mixed methods design that integrated quantitative and qualitative data at the interpretation stage. The researchers collected quantitative data through structured observations to measure learning engagement, responsibility, communication, collaboration, functional independence, and behavioral-emotional regulation. The researchers collected qualitative data through semi-structured interviews with teachers and several selected students to understand their experiences of participation and the social meaning of the learning activities. The intervention involved a small-scale land management project based on smart farming that utilized simple Internet of Things (IoT) sensors such as soil moisture indicators and an automated irrigation system. The findings show a high level of learning engagement (88.5%), increased student responsibility (80%), communication (85.7%), and collaboration (74.2%). The students also demonstrated an average increase of approximately one-third in practical skill mastery compared to the baseline condition, accompanied by a decrease in disruptive behavior, increased attention, greater task independence, and more positive emotional expressions. Interviews reveal that the students began to position themselves as active participants in the learning activities, while teachers interpreted the practice as a contextual learning environment that strengthened students' capabilities through direct experience. The study demonstrates that smart farming based on PjBL can function as an inclusive pedagogical practice that strengthens cognitive, social, and emotional learning outcomes in rural special education schools. The main contribution of this study lies in the development of a socio-material learning approach grounded in local contexts that integrates simple technology, physical activity, and social collaboration in inclusive education.

Keywords: Inclusive Education; Project-Based Learning; Smart Farming, Socio-Material Learning Space; Rural Special Education.

Abstrak

Penelitian ini bertujuan untuk menganalisis penerapan smart farming berbasis Project-Based Learning (PjBL) sebagai ruang belajar sosio-material yang memediasi partisipasi, agensi, dan keterlibatan siswa dalam pendidikan khusus di konteks pedesaan. Penelitian ini dilaksanakan di SLB Muhammadiyah Kutoarjo, sebuah sekolah pendidikan khusus (Sekolah Luar Biasa) yang terletak di wilayah pedesaan di Provinsi Jawa Tengah, Indonesia, dengan melibatkan 35 siswa berusia 7–12 tahun yang memiliki disabilitas intelektual dan gangguan spektrum autisme, serta empat guru pendidikan khusus. Penelitian ini menggunakan desain *mixed methods* konvergen yang mengintegrasikan data kuantitatif dan kualitatif pada tahap interpretasi. Peneliti mengumpulkan

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data kuantitatif melalui observasi terstruktur untuk mengukur keterlibatan belajar, tanggung jawab, komunikasi, kolaborasi, kemandirian fungsional, serta regulasi perilaku-emosi. Peneliti mengumpulkan data kualitatif melalui wawancara semi-terstruktur dengan guru dan beberapa siswa terpilih untuk memahami pengalaman partisipasi dan makna sosial pembelajaran. Intervensi pembelajaran dilakukan melalui proyek pengelolaan lahan kecil berbasis *smart farming* yang memanfaatkan sensor IoT sederhana seperti pengukur kelembapan tanah dan sistem penyiraman otomatis. Hasil penelitian menunjukkan tingkat keterlibatan belajar yang tinggi (88,5%), peningkatan tanggung jawab siswa (80%), komunikasi (85,7%), dan kolaborasi (74,2%). Siswa juga menunjukkan peningkatan keterampilan praktis rata-rata sekitar sepertiga dibandingkan kondisi awal, disertai penurunan perilaku disruptif, peningkatan perhatian, kemandirian tugas, dan ekspresi emosi positif. Wawancara menunjukkan bahwa siswa mulai memposisikan diri sebagai peserta aktif dalam kegiatan belajar, sementara guru menafsirkan praktik ini sebagai ruang pembelajaran kontekstual yang memperkuat kapabilitas siswa melalui pengalaman langsung. Penelitian ini menunjukkan bahwa *smart farming* berbasis PjBL dapat berfungsi sebagai praktik pedagogis inklusif yang memperkuat capaian pembelajaran kognitif, sosial, dan emosional di sekolah luar biasa pedesaan. Kontribusi utama penelitian ini terletak pada pengembangan pendekatan pembelajaran sosio-material berbasis konteks lokal yang mengintegrasikan teknologi sederhana, aktivitas fisik, dan kolaborasi sosial dalam pendidikan inklusif.

Kata Kunci: Pendidikan Inklusif; Project-Based Learning; Smart Farming; Ruang Belajar Sosio-Material; Pendidikan Khusus Pedesaan.

INTRODUCTION

Inclusive education is normatively understood as part of the human rights and social justice agenda within modern education systems (Sabela, 2023; Shaeffer, 2019). Many education policies across different countries emphasize the importance of providing equal learning opportunities for all children, including children with disabilities (Ainscow, 2020; Miles & Singal, 2010; Taneja-Johansson & Singal, 2025; Waisath et al., 2024). However, numerous studies show that inclusive education practices often fail to fully reflect these principles of equality (Hikmat, 2025; Leijen et al., 2021). Many schools place students with disabilities in regular classrooms without transforming the learning structure, pedagogical practices, or social relationships that shape their learning experiences. This condition creates a risk that inclusive education becomes merely administrative compliance with policy rather than a genuine transformation of educational practice (Sumedi et al., 2025).

This gap between normative commitments and educational practice becomes more visible in developing countries, including Indonesia. The Indonesian government has developed various regulations that support inclusive education, yet implementation still faces many structural challenges (Fauziyah et al., 2025). These challenges include limited educational resources, inadequate teacher preparedness, and unequal access to education between urban and rural areas. In rural areas, these conditions often worsen because of limited educational infrastructure, restricted access to specialized education services, and learning systems that still struggle to adapt to the needs of students with disabilities (Isnawati et al., 2025; Maufuriyah, 2018; Rude & Miller, 2018; Somad et al., 2024).

These issues also relate to long-term consequences for the social and economic participation of persons with disabilities. Data from Statistics Indonesia show that approximately 22.97 million persons with disabilities live in Indonesia, and many of them face barriers in accessing quality education and formal employment opportunities (Badan Pusat Statistik, 2024; Tusianti et al.,

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2023). Limited access to educational programs that integrate life skills, vocational training, and entrepreneurship constitutes one of the main factors that restrict the economic independence of persons with disabilities. Several studies demonstrate that practice-oriented and entrepreneurship-based educational approaches can increase independence, self-confidence, and economic participation among students with disabilities (Govindasamy et al., 2021; Maufuriyah, 2018).

In addition to affecting economic participation, educational exclusion also influences the social participation and civic engagement of persons with disabilities in community life. Studies show that persons with disabilities still encounter various forms of social discrimination that limit their access to public services, higher education, and participation in social life (Dewi et al., 2022; Pangestuti & Pribadi, 2022). Research conducted in Riau, Indonesia, demonstrates that systemic discrimination against persons with disabilities can produce psychological impacts and reduce their engagement in community activities (Supriyanto et al., 2025). Similar barriers also appear in access to public services and transportation, which indirectly restrict access to education and employment opportunities (Widjaja, 2025).

In everyday educational practice, many schools still apply an integration approach that requires students with disabilities to adapt to existing education systems (Rahajeng et al., 2024; Triyanto et al., 2023). This approach risks producing what scholars describe as symbolic inclusion, a condition in which students with disabilities are formally accepted in schools but still experience limitations in learning participation and decision-making processes (Florian, 2014; Slee, 2011). Previous studies emphasize the importance of pedagogical innovation, teacher readiness, and inclusive school cultures to create more participatory learning environments (Fionita & Nurjannah, 2024; Sari et al., 2022; Sunardi, et al., 2011).

In rural contexts, education often maintains a close relationship with community life and local economic activities. Limited educational resources frequently require schools to develop more contextual and experience-based learning practices that connect students' learning experiences with everyday community activities. This condition opens opportunities for community-based learning approaches that link educational experiences with local social and economic activities (Gruenewald, 2003; Odeh & Lach, 2024; Wilson, 2025).

One practice that has recently developed in this context involves the implementation of smart farming. Smart farming refers to the use of digital technologies and intelligent systems to improve productivity, efficiency, and sustainability in the agricultural sector (Balafoutis et al., 2020; Madushanki et al., 2019; Wolfert et al., 2017) . In educational contexts, smart farming often functions as a medium for teaching science, technology, and entrepreneurship. However, most studies still treat smart farming primarily as a technical or vocational training activity that focuses on operational skills without considering its social and pedagogical dimensions within inclusive learning environments (Kolb, 2013; Lave & Wenger, 1991).

Research on inclusive education, project-based learning, and educational technology has developed across several main trends. The first trend highlights the pedagogical effectiveness of active learning approaches such as Project-Based Learning (PjBL) in improving student engagement. Several studies show that PjBL can enhance collaboration, problem-solving skills, and student motivation because this learning model focuses on real activities and experiential learning (Bell, 2010; Kokotsaki et al., 2016; Krajcik & Czerniak, 2018; Nilholm, 2021; Thomas, 2000).

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However, most of these studies emphasize classroom learning effectiveness and rarely examine how learning practices function as social spaces that shape the participation and agency of students with disabilities.

The second trend examines the application of educational technology and agricultural technology in learning processes. Research on smart farming in education generally focuses on the development of technical skills, technological understanding, and vocational training for students (Balafoutis et al., 2020; Madushanki et al., 2019; Navarro et al., 2020). Some studies show that IoT-based projects can improve students' understanding of technological and environmental concepts (Rahmawati et al., 2025). Nevertheless, this approach remains dominated by a technocentric perspective that views technology primarily as a learning tool without examining the social relationships that emerge during the learning process.

The third trend emerges from critical disability studies, which examine power relations, social stigma, and institutional structures that influence the educational experiences of students with disabilities (Goodley, 2016; Shakespeare, 2014). Research in this field shows that inclusive education does not only concern instructional methods but also involves how schools construct social spaces that enable or constrain student participation. However, most studies in this field have not sufficiently explored technology-based and community-based learning practices as social spaces that mediate the participation of students with disabilities.

Based on this literature review, several research gaps require further investigation. First, only a limited number of studies analyze concrete learning practices as social processes that can strengthen the agency and participation of students with disabilities in rural areas (Bjørnerås et al., 2024; Kumar et al., 2025). Second, research on PjBL and educational technology mostly focuses on pedagogical effectiveness and rarely examines learning practices as social spaces that connect schools with community life and local economic activities. Third, research on smart farming in education remains dominated by technical and vocational approaches and therefore pays limited attention to the social, relational, and contextual dimensions of inclusive learning environments.

Based on these research gaps, this study aims to analyze how smart farming–based learning practices implemented through the Project-Based Learning approach create a socio-material learning space that enables the participation, agency, and engagement of students with disabilities within rural special education contexts. The study also examines how these learning practices connect students' learning experiences with social relationships, work experiences, and local economic contexts within the school environment.

Therefore, this study proposes the hypothesis that the implementation of smart farming based on Project-Based Learning can increase the participation, learning engagement, and independence of students with disabilities through the creation of a socio-material learning space that integrates physical activities, social collaboration, and the use of simple technology within rural educational contexts.

RESEARCH METHODS

This study analyzes how the implementation of smart farming through the Project-Based Learning (PjBL) approach supports student learning engagement, functional independence, and behavioral regulation within the context of special education in rural areas. The primary unit of analysis in this study is the change in student behavior and participation during project-based learning activities. The researchers operationalize this unit of analysis through three main indicators: learning engagement, responsibility and independence in completing practical tasks, and behavioral and emotional regulation during learning activities. In addition to the primary unit of analysis, the study also uses two supporting units of analysis to provide contextual understanding of the learning process: teachers as institutional actors who influence the implementation of learning practices and the school as an organizational environment that enables or constrains the implementation of instructional innovation.

This study employs a mixed methods design using a convergent design approach. The researchers collect quantitative and qualitative data in parallel and integrate both types of data during the interpretation stage of the research findings (Creswell, 2012). The researchers select the mixed methods approach because the study aims not only to measure the level of student engagement and behavioral changes quantitatively but also to understand students' learning experiences and the social meaning of the learning practices. Quantitative data allow the researchers to document patterns of student engagement, responsibility in practical tasks, and behavioral regulation during learning activities. Meanwhile, qualitative data help explain the social mechanisms that occur during the learning process and the contextual conditions that influence student participation. The researchers design this study as an in-depth case study conducted in a single special education school located in a rural area in order to understand the contextual implementation of instructional innovation within a specific social and institutional environment.

The study takes place at SLB Muhammadiyah Kutoarjo, a special education school located in a rural area of Central Java Province, Indonesia. The school serves students with various types of disabilities who come from agrarian communities where agricultural activities form an important part of local social life. The research participants consist of 35 students aged 7–12 years who are enrolled at the elementary school level. Most students have diagnoses of intellectual disability and autism spectrum disorder. The study also involves four special education teachers who are responsible for classroom instruction. The researchers apply a total population sampling technique by including all students who participate in the smart farming activities during the research period. The teachers serve as key informants because they play important roles in designing, implementing, and reflecting on the learning process.

The researchers collect data through three primary techniques: structured classroom observation, semi-structured interviews, and field notes. Classroom observation documents patterns of student engagement, responsibility in practical tasks, and behavioral and emotional regulation during learning activities. Observers use structured observation sheets to record student behavioral indicators within specific time intervals using momentary time sampling and event recording techniques. Meanwhile, the observers record students' practical skills based on the level of completion of each task step during the project activities. The researchers conduct semi-structured interviews with four teachers and six students who are purposively selected based on their verbal communication ability, willingness to participate, and variation in levels of engagement during project activities. The interviews aim to understand students' learning experiences and teachers' interpretations of changes in student participation and independence during the learning process. The instructional intervention takes place through a small-scale agricultural land management project based on smart farming that utilizes soil moisture sensors, a simple irrigation system, and visual indicators that help students understand plant conditions.

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Figure 1. Stages of Smart Farming Learning Activities Based on Project-Based Learning

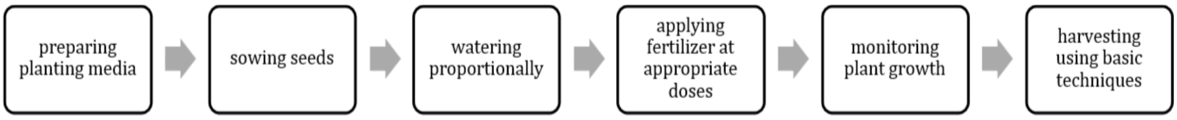

Figure 1 illustrates the sequence of project activities carried out by students during the learning intervention. These activities include preparing the planting media, planting seeds, watering plants proportionally, applying fertilizer with the appropriate dosage, monitoring plant growth, and harvesting using simple techniques. The researchers design this sequence of activities to train students' practical skills, responsibility, and collaboration during project-based learning activities.

Figure 2. Documentation of Smart Farming Learning Activities Among Students in a Special Education School

The researchers analyze quantitative data using descriptive statistics by calculating percentages, means, and value ranges for each indicator of student engagement, responsibility in practical tasks, functional independence, and behavioral regulation during learning activities. The researchers also use visual graphs to identify patterns of behavioral change among students during the implementation of the project. The researchers interpret these changes as behavioral changes within the context of learning activities rather than as experimental causal effects. Therefore, the researchers use the initial sessions of the project activities as a reference point to compare the development of student behavior throughout the intervention. The researchers analyze qualitative data using the thematic analysis approach developed by Braun and Clarke (2006). The researchers conduct inductive coding to identify themes emerging from empirical data and then map these themes onto the study's main analytical domains: student engagement, independence in practical tasks, and behavioral regulation within inclusive learning contexts. Finally, the researchers

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integrate quantitative and qualitative data during the interpretation stage by comparing observational findings with participant narratives in order to obtain a more comprehensive understanding of how smart farming practices based on Project-Based Learning support student engagement and participation in the context of rural special education schools.

RESULTS AND DISCUSSION

Increase in Student Engagement in Smart Farming Learning Based on Project-Based Learning

The first aspect analyzed in this study is student engagement during the implementation of smart farming learning based on Project-Based Learning (PjBL). The researchers measure student engagement through four main indicators: active involvement, functional communication, responsibility in completing tasks, and collaboration in group activities. The researchers use these four indicators to operationalize the concept of student engagement in a more concrete and measurable way within project-based learning activities (Fredricks et al., 2004).

The observation results show that student engagement increased consistently throughout the implementation of the program. During the initial stage of the activities, most students demonstrated relatively low levels of engagement. Many students still waited for instructions from the teacher and did not yet demonstrate initiative in completing tasks. The baseline data show that the level of student engagement across all indicators ranged from 28.3% to 41.2%.

Behavioral changes began to appear during the middle phase of the program implementation. By the fourth week, students began to demonstrate increased participation in routine activities such as watering plants, checking soil moisture indicators, and independently caring for plants. Student engagement increased significantly across all observed indicators. This improvement did not occur in only one or two indicators but appeared consistently across all aspects of student engagement.

Table 1 presents the development of student engagement indicators during the implementation of smart farming learning based on PjBL.

Table 1. Development of Student Engagement Indicators in Smart Farming Activities Based on PjBL

Indicator	Operational Definition	Pre (%)	Week 4 (%)	Post (%)	Improvement Range	Disaggregated Data (ID/ASD)
Involvement	Active participation in ≥70% of activity intervals	41.2	67.5	88.5	47.3	ID: 90% (18/20) · ASD: 86% (13/15)
Communication	Completion of tasks independently in ≥80% of opportunities	38.0	60.4	85.7	47.7	ID: 85% (17/20) · ASD: 73% (11/15)

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Responsibility	≥3 meaningful communication actions in one session	35.4	58.2	80.0	44.6	ID: 90% (18/20) · ASD: 80% (12/15)
Collaboration	Participation in ≥2 group tasks per session	28.3	52.7	74.2	45.9	ID: 80% (16/20) · ASD: 67% (10/15)

Source: Processed research data, 2025.

Table 1 shows that all engagement indicators increased substantially from the initial stage to the final stage of the program. The active involvement indicator increased from 41.2% to 88.5%. Functional communication increased from 38.0% to 85.7%. The responsibility indicator increased from 35.4% to 80.0%. Meanwhile, the collaboration indicator increased from 28.3% to 74.2%.

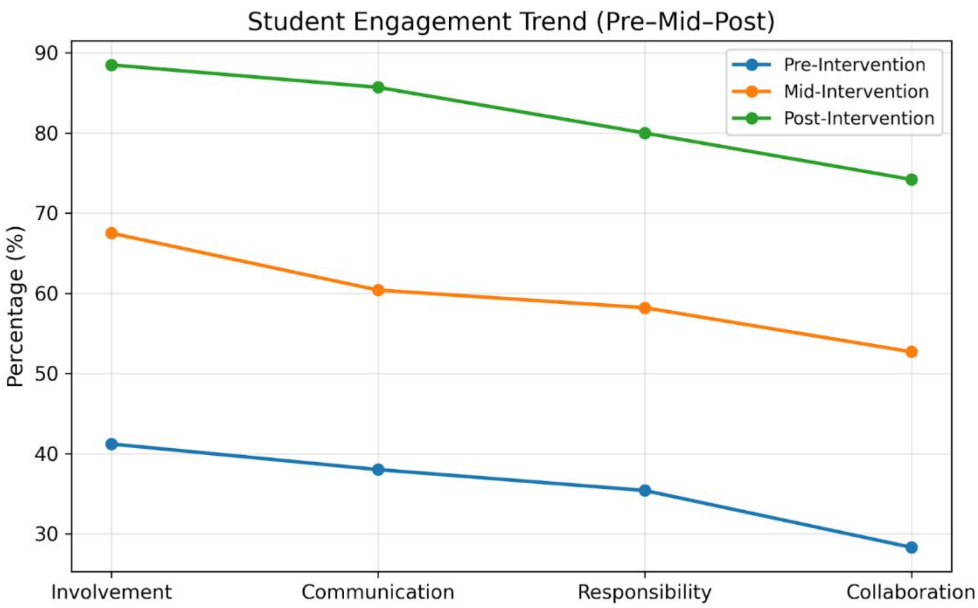

Figure 3. Student Engagement Trends During the Smart Farming Intervention Based on Project-Based Learning (Pre-Intervention, Mid-Intervention, and Post-Intervention)

Figure 3 illustrates that all engagement indicators increased consistently from the pre-intervention phase to the post-intervention phase. The involvement indicator showed the highest level of improvement compared to the other indicators. This pattern indicates that project-based learning activities encouraged students to participate directly in practical learning activities.

The functional communication indicator also showed a substantial increase during the intervention period. Students began to demonstrate improved communication skills when asking for assistance, giving simple instructions to peers, and asking questions related to the activities.

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Meanwhile, the responsibility and collaboration indicators increased more gradually but steadily throughout the program implementation. This pattern suggests that more complex social skills such as group cooperation developed after students became familiar with the routine of the learning activities.

The analysis based on types of disability also reveals a relatively consistent pattern of improvement. Students with intellectual disabilities demonstrated slightly higher levels of engagement compared to students with autism spectrum disorder. However, both groups showed significant improvement during the implementation of the project-based learning activities.

Observation data also indicate that the increase in engagement did not occur linearly but developed gradually as students became familiar with the routine activities. During the early phase of the implementation, students showed greater interest in simple technologies such as soil sensor indicators. During the later phase, student engagement developed into more stable participation in routine activities such as plant care and collaborative group work.

These quantitative findings are supported by qualitative data from teacher interviews. Teachers reported that students began to demonstrate initiative in completing tasks without waiting for direct instructions. One teacher explained that behavioral changes began to appear in the middle of the program when students started remembering the activity routines independently.

> “In the fourth week, students began to ask on their own when it was time to water the plants. They started to feel that the plants were their responsibility.” (Teacher 1, interview, July 18, 2025).

This statement indicates that students no longer simply followed the teacher’s instructions but began to internalize the activity routines as part of their own responsibilities. This pattern also appears in the statement of one student who demonstrated an understanding of the purpose of the activity.

> “We will water them again tomorrow so the plants can grow.” (Student A, 10 years old, interview, July 18, 2025).

In addition, field observation notes reveal more subtle but significant behavioral changes. Several students with autism spectrum disorder who initially showed resistance to sensory activities such as touching soil began to participate actively in planting activities. Meanwhile, students with intellectual disabilities demonstrated an increase in attention duration during learning activities, from very short intervals to approximately 20 to 25 minutes within a single activity session.

A longitudinal analysis conducted over eight weeks shows that the involvement and communication indicators increased more rapidly during the early phase of the program implementation. In contrast, the responsibility and collaboration indicators developed more gradually and reached their highest levels during the final phase of the activities. This pattern indicates that mastery of routine activities and the use of simple tools provided a foundation for the development of more complex social skills such as cooperation and group coordination.

Overall, the findings indicate that the implementation of smart farming based on Project-Based Learning significantly increased student engagement in the context of rural special education. Both quantitative and qualitative data consistently demonstrate that this project-based

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learning activity encouraged greater active participation, functional communication, responsibility in completing tasks, and collaborative working practices among students.

Mastery of Practical Skills in Smart Farming Learning Based on Project-Based Learning

The primary objective of the smart farming intervention based on Project-Based Learning (PjBL) in this study is to develop practical skills related to agricultural activities. The researchers evaluate the development of students' practical skills using a performance-based assessment rubric. The researchers conduct the assessment at two time points: the beginning of the program (baseline) and the end of the program in the eighth week. The researchers break down each practical skill into several sequential subtasks that observers can directly observe. The study defines skill mastery as the ability of students to complete all subtasks within one skill domain independently and accurately.

The quantitative analysis shows a significant and consistent increase across all measured skills. The average level of students' practical skill mastery increases by 33.4 percentage points, from 44.6% at baseline to 78.0% at the end of the program. All skill domains show large effect sizes, with Cohen's d values greater than 1.4. These results indicate that project-based learning activities produce a strong educational impact on the development of students' practical skills.

Table 2 presents the development of students' practical skill mastery levels.

Table 2. Levels of Practical Skill Mastery in Smart Farming Learning Based on PjBL

Practical Skill	Key Subtasks Assessed	Initial Mastery (Mean %)	Final Mastery (Mean %)	Increase (Percentage Points)	Effect Size (Cohen's d)
Seed Planting	(a) Selecting appropriate seeds; (b) preparing planting media; (c) creating planting holes; (d) placing seeds; (e) covering the planting media	45%	78%	+33	1.82 (Large)
Proportional Watering	(a) Checking soil moisture sensors; (b) deciding whether watering is necessary; (c) measuring water	50%	85%	+35	2.10 (Large)

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	volume; (d) watering the plants				
Fertilizing with Correct Dosage	(a) Identifying fertilizer type; (b) using measuring tools; (c) applying the correct dosage; (d) mixing fertilizer with soil	38%	70%	+32	1.45 (Large)
Basic Harvesting Techniques	(a) Identifying plants ready for harvest; (b) using harvesting tools safely; (c) cutting at the correct stem point; (d) placing harvested crops	42%	75%	+33	1.65 (Large)
Daily Plant Care	(a) Observing plant conditions; (b) removing dead leaves; (c) recording plant growth; (d) organizing the planting area	48%	82%	+34	1.95 (Large)
Overall Average		44.6%	78.0%	+33.4	1.79 (Large)

Source: Processed research data, 2025.

Table 2 shows that all practical skills increased significantly after the implementation of the project-based learning intervention. The proportional watering skill demonstrates the highest level of mastery at the end of the program, increasing from 50% to 85%. Meanwhile, the fertilizing skill shows the lowest initial mastery level at 38%, but it still increases significantly to reach 70% at the end of the program.

The visualization of the development of students' practical skill mastery during the intervention appears in Figure 4.

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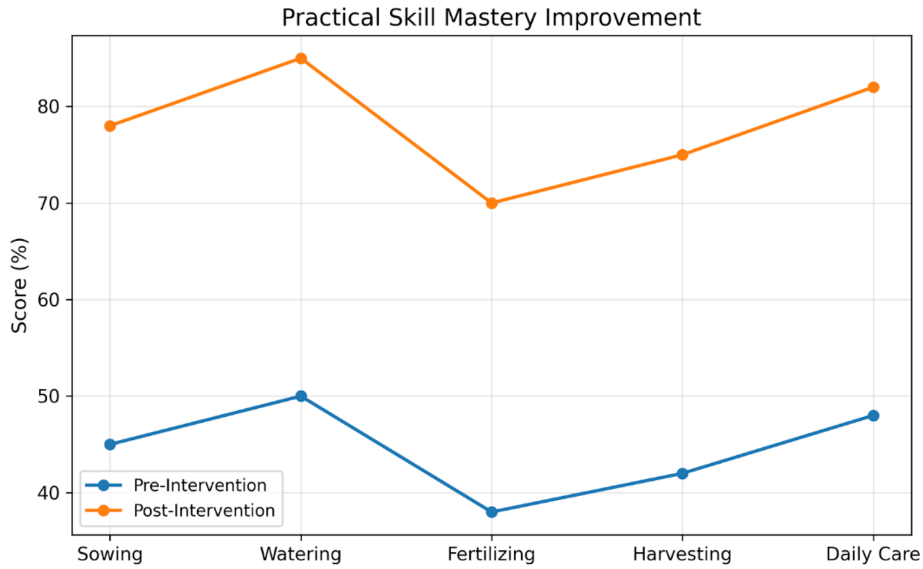

Figure 4. Development of Students' Practical Skill Mastery in Smart Farming Learning Based on PjBL

Figure 4 shows that all skill domains increase from the beginning to the end of the program. Although all skills improve, the relative order of difficulty remains consistent. Proportional watering remains the easiest skill for students to master, while fertilizing remains the most challenging skill.

At the beginning of the program, proportional watering represents the easiest skill for students to learn, with an initial mastery level of 50%. This pattern likely occurs because the cause-and-effect relationship between plant condition and watering action is clearly observable. In contrast, fertilizing represents the most difficult skill at the initial stage because the activity requires more precise motor coordination and an understanding of dosage concepts that are more abstract.

The analysis based on types of disability also reveals differences in skill development patterns. Students with intellectual disabilities show an average improvement of 35.2 percentage points, increasing from 46.1% to 81.3%. Meanwhile, students with autism spectrum disorder show an improvement of 30.8 percentage points, increasing from 42.5% to 73.3%.

These differences indicate that students with intellectual disabilities tend to master routine and repetitive skills more quickly. The consistent structure of activities helps students develop work habits and increase their confidence in completing tasks. In contrast, students with autism spectrum disorder require a longer adaptation period, especially for activities that involve sensory stimuli such as the smell of fertilizer and the texture of soil. Nevertheless, students with autism spectrum disorder demonstrate significant improvement in task accuracy by the end of the program.

The weekly formative evaluation also shows that the learning process does not develop linearly. The most significant improvement occurs between the third and fifth weeks, when students begin to engage more fully in the plant growth cycle. During the early phase of the

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activities, skills that involve the use of tools tend to develop more slowly. However, after students become familiar with the tools, the accuracy of task completion increases significantly.

These quantitative findings receive further support from qualitative data obtained through field observations and teacher interviews. Teachers report that agricultural skills taught through smart farming learning based on PjBL are easier for students to understand because the activities are concrete, sequential, and produce observable outcomes.

During the initial stage of the program, most students still require verbal prompts and physical assistance from teachers to complete subtasks, especially in activities that involve measurement or tool use such as fertilizing and harvesting. However, after students repeatedly perform the activities within a consistent structure, teachers begin to observe the emergence of independent task completion. Students gradually remember the sequence of tasks and complete activities with greater accuracy without intensive assistance from teachers.

One teacher explains that the most visible changes occur in watering and daily plant care skills.

> “When the plants look wilted or healthy, the students can see it themselves. That helps them understand when the plants need watering and when they do not.” (Teacher 2, interview, July 20, 2025).

Observation data also show that several students demonstrate procedural understanding through nonverbal actions. In several situations, students point to the sensor indicator or immediately perform corrective actions without waiting for additional instructions from teachers. Teachers interpret this behavior as meaningful procedural understanding even when students have limited verbal communication.

> “Some students do not speak much, but when they notice changes in the sensor indicator, they immediately take the measuring tool. That shows that they already understand what they need to do.” (Teacher 4, interview, July 20, 2025).

As students’ skill mastery improves, students begin to assume different roles in group activities based on their individual abilities. Some students take the role of measuring water volume, others prepare the planting media, while other students assist in the harvesting process. This naturally emerging role distribution helps maintain student engagement throughout the entire cycle of learning activities.

The findings show that the improvement of students’ practical skills appears not only in quantitative data but also in functional behavioral changes during smart farming activities. The skills that students learn do not remain isolated technical procedures but become integrated into meaningful real-world activities. Although some students have limitations in verbal communication, they still demonstrate conceptual understanding through actions, simple decision-making, and consistent completion of task sequences.

This study shows that smart farming learning based on Project-Based Learning encourages a transition from structured instructional practice toward more independent and meaningful skill mastery. This development provides an important foundation for increasing students’ self-confidence and for supporting potential vocational skill development in the future.

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Behavioral and Emotional Regulation of Students in Smart Farming Learning Based on Project-Based Learning

The third aspect analyzed in this study is students' behavioral and emotional regulation during the implementation of smart farming learning based on Project-Based Learning (PjBL). Behavioral and emotional regulation refers to students' ability to control their behavior, maintain attention toward tasks, demonstrate independence in activities, and express positive emotions during learning activities. The study documents these changes through a multi-method approach that combines systematic behavioral observation, teacher-recorded behavior frequency logs, and qualitative analysis of students' emotional expressions during learning sessions.

The results show that the smart farming intervention based on PjBL significantly influences students' behavioral and emotional regulation. The structured nature of the learning activities, the presence of rich sensory stimuli, and the orientation toward observable outcomes create a learning environment that supports the development of students' self-regulation abilities.

Teacher behavior logs collected during twelve learning sessions show substantial changes across four primary indicators of behavioral and emotional regulation: disruptive behavior, sustained attention duration, task independence, and positive emotional expression. These changes appear in Table 3.

Table 3. Changes in Behavioral and Emotional Regulation Indicators Before and After the Intervention

Regulation Indicator	Operational Definition	Pre-Intervention Mean (per 45-minute session)	Post-Intervention Mean	Change (%)	Statistical Significance
Disruptive Behavior	Frequency of behaviors such as shouting, task refusal, leaving seat, or damaging tools	6.2 events	1.8 events	-71.0%	$p < 0.001$
Sustained Attention Duration	Average duration of focused attention on the main activity	3.1 minutes	8.4 minutes	+171.0%	$p < 0.001$
Task Independence	Percentage of step-by-step task completion without teacher assistance	40%	75%	+87.5%	$p < 0.01$
Positive Emotional Expression	Frequency of smiles, enthusiastic	4.5 events	10.6 events	+135.6%	$p < 0.001$

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	gestures, or positive communication during activities	

Source: Processed research data, 2025.

Table 3 shows that all behavioral and emotional regulation indicators improved significantly after the learning intervention. The frequency of disruptive behavior decreased sharply by 71%, from an average of 6.2 events per session to 1.8 events. This decrease indicates a substantial change in classroom behavioral dynamics during learning activities.

Students' attention duration also increased significantly. The average focus duration increased from 3.1 minutes to 8.4 minutes. This increase indicates that students were able to maintain their attention on tasks for longer periods during smart farming activities. Task independence also increased from 40% to 75%, which indicates that more students were able to complete activity sequences without verbal or physical assistance from teachers.

Another change appeared in the increase of positive emotional expressions during learning activities. The frequency of positive emotional expressions increased from an average of 4.5 events to 10.6 events per session. These expressions included smiles, enthusiastic gestures, and verbal statements that reflected pride or enjoyment regarding the outcomes of the activities.

The visualization of the development of students' behavioral and emotional regulation indicators during the intervention appears in Figure 5.

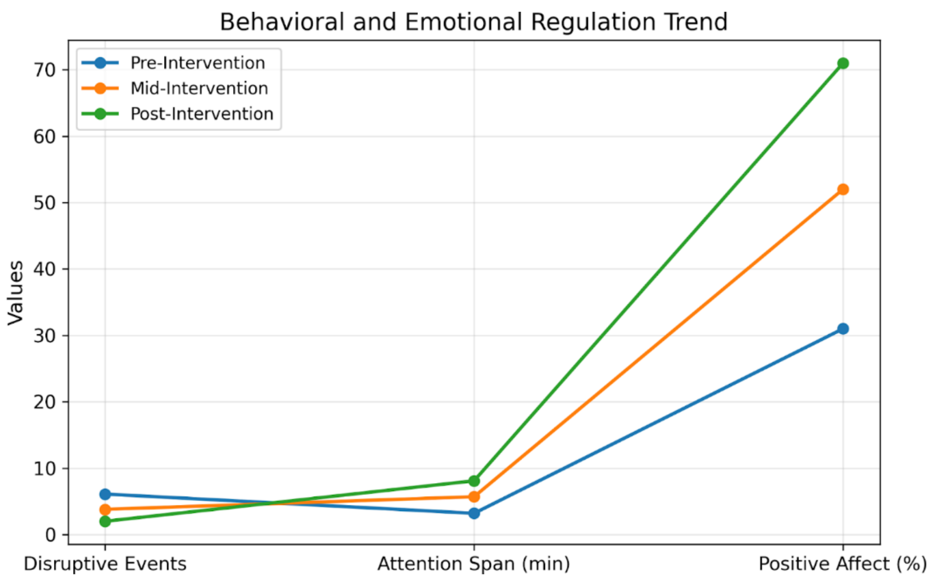

Figure 5. Trends in Changes in Students' Behavioral and Emotional Regulation During the Smart Farming Intervention Based on PjBL

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Figure 5 shows that changes in students' behavioral and emotional regulation developed gradually throughout the intervention period. At the beginning of the program, students' attention levels varied considerably and often increased temporarily when students first interacted with new tools or technologies. However, during the middle phase of the program, students' attention levels began to show more stable patterns and no longer depended on the novelty of the activities.

Observation data also indicate that project-based learning activities created dynamics of co-regulation among students. In several situations, the focused behavior demonstrated by one student influenced the behavior of other students nearby, which created a calmer learning environment. This situation formed small groups of students who were able to maintain shared attention toward the ongoing activities.

In addition, the level of student independence in completing tasks showed different patterns across activity types. Routine activities supported by simple technologies, such as activating the automatic irrigation system using a large button, demonstrated the highest level of independence with a success rate of approximately 88%. In contrast, activities that required repeated evaluation, such as checking plant health, still required additional assistance from teachers, although the success rate continued to improve during the intervention period.

The use of visual schedules and illustrated step-by-step guides also played an important role in supporting the development of student independence. During the initial phase of the activities, most students still relied on these guides to start and complete tasks. However, over time, students' dependence on the visual guides gradually decreased. Students increasingly initiated activities independently and completed task sequences without direct assistance from teachers.

Observation data also reveal changes in students' emotional expression and self-perception. During several early sessions, students often showed signs of discomfort when they encountered tasks they considered difficult, such as frowning, dropping tools, or temporarily stopping the activity. However, as students gained more experience and confidence, these responses gradually shifted toward more adaptive self-regulation strategies, such as taking deep breaths or reviewing the available visual guides.

These changes were accompanied by clearer expressions of positive emotions during learning activities. Some students showed anticipatory behavior, such as smiling when entering the garden area or pointing to the plants they were responsible for. Changes also appeared in the way students referred to the plants they cared for. Some students began using possessive expressions such as "my plant" or action-oriented statements such as "I watered it." These expressions indicate that students began to perceive themselves as active agents in the learning activities.

Field observations also show that students' emotional experiences often developed collectively. The excitement of one student when observing early plant growth often triggered similar responses among other students in the group. Conversely, when the condition of a plant appeared unfavorable, students also demonstrated shared concern about caring for the plant.

These quantitative findings are reinforced by interview results with teachers. One teacher explained that behavioral changes became clearly visible among several students who previously experienced difficulties managing their emotions.

> "One student who previously experienced frequent tantrums whenever routines changed became the most consistent student in maintaining the plant watering schedule. The

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technology provided a stable structure, while the plants provided a meaningful reason to maintain that routine." (Teacher 3, interview, July 18, 2025).

Another teacher also explained that the garden area often functioned as an emotional de-escalation space for students.

"When students feel anxious in the classroom, we sometimes invite them to complete a short task in the garden, such as checking the sensor. The activity helps them calm down and return to learning with a more stable emotional condition." (Teacher 1, interview, July 18, 2025).

The findings indicate that smart farming learning based on Project-Based Learning not only increases student engagement and practical skills but also contributes to the development of students' behavioral and emotional regulation. A learning environment that is concrete, structured, and provides immediate feedback helps students develop the ability to control their behavior, maintain attention toward tasks, and express positive emotions throughout the learning process.

DISCUSSION

This study shows that the implementation of smart farming learning based on Project-Based Learning (PjBL) produces significant changes in student engagement, practical skill mastery, and behavioral and emotional regulation in the context of rural special schools. Observation data show that student engagement increased consistently during the intervention period. Active engagement reached 88.5%, functional communication reached 85.7%, responsibility reached 80%, and collaboration reached 74.2%. In addition, students' practical skill mastery increased from an average of 44.6% at the beginning of the program to 78.0% at the end of the program, with large effect sizes across all skill domains. Changes also appeared in behavioral and emotional regulation. The frequency of disruptive behavior decreased by 71%, the duration of task attention increased from 3.1 minutes to 8.4 minutes, task independence increased from 40% to 75%, and positive emotional expression more than doubled during the intervention.

Qualitative findings support these quantitative results. Teachers reported that students began to show initiative in performing tasks without waiting for direct instructions. Several students also began to express a sense of ownership over the activities they performed, for example through expressions such as "my plant" or "I watered it." These changes indicate that students did not merely participate mechanically in learning activities but began to position themselves as active agents in the learning process.

The increase in student engagement and independence in this study relates to the characteristics of project-based learning that connect learning activities with real-life experiences. In smart farming activities, students directly engage in a sequence of activities with clear goals, such as planting, watering, and caring for plants. These activities provide immediate feedback on students' actions, which allows students to understand the cause-and-effect relationship between their actions and the outcomes produced.

A learning environment that is concrete and practice-oriented also helps students maintain attention to tasks. In the context of special education, activities that involve sensory experiences and structured routines often help students develop self-regulation and emotional stability. This pattern appears in the increased duration of student attention and the reduction of disruptive behavior during the activities.

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In addition, project-based learning creates a social structure that encourages collective participation. In smart farming activities, students do not work only individually but also share roles within groups, such as watering plants, measuring fertilizer dosage, or recording plant growth. This role distribution creates more meaningful social interaction compared to desk-based classroom learning. This situation allows students to build a social identity as contributors to shared activities rather than merely as recipients of teacher instructions.

The findings of this study can be positioned within three major trends in the literature on inclusive education and educational technology. The first trend emphasizes the pedagogical effectiveness of active learning approaches such as Project-Based Learning. Several studies show that PjBL can increase student engagement, collaboration, and problem-solving abilities because learning focuses on real activities and direct experiences (Bell, 2010; Kokotsaki et al., 2016; Krajcik & Czerniak, 2018; Nilholm, 2021; Thomas, 2000). The findings of this study support this literature by demonstrating a significant increase in student engagement in the context of special education. However, unlike many previous studies that emphasize pedagogical effectiveness in classrooms, this study shows that project-based learning also functions as a social space that shapes participation and agency among students with disabilities.

The second trend examines the use of educational technology and agricultural technology in learning. Studies on smart farming in education generally emphasize the development of technical skills and understanding of technological concepts (Balafoutis et al., 2020; Madushanki et al., 2019; Navarro et al., 2020). Several studies show that projects based on the Internet of Things can improve students' understanding of technology and environmental systems (Rahmawati et al., 2025). The findings of this study extend that perspective by showing that simple technologies do not only function as learning tools but also serve as media that help students build work routines, independence, and social interaction during learning activities.

The third trend comes from critical disability studies, which highlight power relations and social structures that shape the educational experiences of students with disabilities (Goodley, 2016; Shakespeare, 2014). Research in this field shows that inclusive education involves not only teaching methods but also the ways in which schools construct social spaces that enable or constrain student participation. The findings of this study show that project-based learning practices can function as social spaces that mediate such participation. Smart farming activities allow students with disabilities to take active roles in activities that carry social and economic meaning in rural environments.

From a historical perspective, the findings of this study indicate a shift in special education practices from passive learning models toward more participatory learning models. In many special education contexts in Indonesia, learning processes still rely heavily on repetitive methods and desk-based activities that position students as recipients of instructions rather than active participants in learning. The results of this study show that project-based learning can create a learning environment that is more dynamic, contextual, and oriented toward real experiences. These findings align with modern inclusive pedagogy, which positions students as active subjects in learning and emphasizes the importance of engagement, collaboration, and direct experience in constructing understanding (Mitchell, 2020). Several studies in Indonesia also show that participatory learning approaches can significantly improve student engagement and learning outcomes. For example, the implementation of cooperative learning models based on participation

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such as Think Pair Square has been shown to increase student learning outcomes by up to 47%, compared with control classes that improved only about 18%, because the learning process encourages interaction, group discussion, and critical thinking activities (Palupi & Budiyanto, 2019). These findings reinforce the argument that participatory learning approaches, including project-based learning, have strong potential to transform educational practices from teacher-centered instruction toward more active, collaborative, and student-centered learning processes.

From a social perspective, smart farming activities transform classroom spaces and school yards into productive social spaces. In these activities, students build social interaction through role distribution, group cooperation, and shared responsibility for the plants they care for. This process creates new social dynamics in which students begin to see themselves as individuals capable of contributing to collective activities. These findings show that learning occurs not only at the cognitive level but also through processes of social learning that emerge through interaction, collaboration, and shared experiences in real activities. Several studies in Indonesia also demonstrate that social and collaborative learning approaches can strengthen students' cooperation skills, leadership abilities, and social awareness when students participate in community-based projects and experiential learning activities (Kiettikunwong et al., 2025; Purbasari et al., 2025). In this context, smart farming functions as a social space that enables students to develop the capacity to participate, share responsibilities, and construct social identities as productive members of learning groups.

From an ideological perspective, the Project-Based Learning approach in this study reflects a shift in educational paradigms from teacher-centered instruction toward student-centered learning. This approach aligns with the capability approach, which emphasizes the importance of expanding individuals' opportunities to develop their capabilities and to live lives that they value as meaningful (Nussbaum, 2008). Capability-based approaches contribute to strengthening competency development, independent learning reflection, and collaborative abilities in educational processes, particularly when learners actively participate in contextual and experience-oriented learning environments. This approach highlights the importance of developing individual capacities through learning processes that create opportunities for reflection, independent learning, and social interaction in both academic activities and practical experiences (Handayani et al., 2021). In addition, studies on the application of the capability approach in the context of technology and education in developing countries show that learning opportunities, institutional support, and access to educational resources play important roles in expanding individuals' capabilities to utilize knowledge and technology meaningfully (Limaj & Bilali, 2018). Other research in Indonesia also shows that the capability approach can help explain how technology and social resources can improve individual well-being and capacity to participate independently in economic and social activities (Anwar & Johanson, 2015).

Although this study shows significant improvements in student engagement and skills, the results must be interpreted cautiously. The observed changes primarily occur at the pedagogical and psychosocial levels within the school environment. The increase in student engagement and independence indicates the development of individual capacity in the learning context, but these findings cannot yet be interpreted directly as broader forms of social or economic empowerment. In addition, the relatively short duration of the intervention limits the study's ability to assess the long-term sustainability of the observed changes. Changes in behavioral regulation and student

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engagement may still be influenced by the novelty effect of learning activities, which requires careful interpretation of the observed impacts. The literature on the sustainability of educational interventions shows that changes in behavior and engagement often require long-term support, including implementation consistency, institutional support, and longitudinal follow-up research to ensure that program impacts persist over time (Christiansen et al., 2021; Watts et al., 2019). Other studies also emphasize that sustained impacts of educational interventions can usually be identified only through long-term studies that monitor student development after the intervention program ends (Bianchi et al., 2022). Therefore, further research using longitudinal designs is necessary to assess whether increases in student engagement, independence, and self-regulation can develop into more stable and sustainable changes in inclusive educational practice.

This study shows that smart farming learning based on Project-Based Learning has strong potential as a pedagogical approach that supports inclusive education practices in rural special schools. Learning activities that integrate real-world experiences, simple technological tools, and collaborative group work significantly increase student engagement, strengthen independence in task completion, and support the development of behavioral and emotional regulation in school-based learning contexts. However, the implications of these findings remain primarily at the pedagogical and psychosocial levels within the school environment, and therefore the results cannot yet be interpreted as broader forms of social or economic empowerment. The development of similar learning programs should therefore include sustained institutional support and collaboration with broader actors, such as families, local communities, and agricultural networks. The involvement of these stakeholders is important to expand students' learning spaces beyond the school context into broader social practices within rural communities. In addition, future studies should develop longitudinal research designs to assess the sustainability of observed changes and to understand how project-based learning practices can contribute more consistently to strengthening capacity, social participation, and inclusion for students with disabilities over the long term.

CONCLUSION

This study shows that the implementation of smart farming based on Project-Based Learning (PjBL) can increase student engagement, functional independence, practical skill mastery, and behavioral and emotional regulation in the context of rural special education. Learning activities that integrate real agricultural practices, the use of simple sensor-based technology, and collaborative group work create a learning environment that is more contextual, participatory, and meaningful for students with intellectual disabilities and autism spectrum disorder. The findings indicate that student engagement increased significantly in aspects of communication, responsibility, and collaboration, followed by improvements in agricultural practical skills, a reduction in disruptive behavior, and an increase in sustained attention to tasks. These results indicate that project-based learning practices can function as a socio-material learning space that supports active student participation and the development of individual capacities in learning activities that are relevant to rural life contexts.

From a scientific perspective, this study contributes to the field of inclusive education by expanding the understanding of project-based learning not only as a pedagogical strategy but also as a social learning space that shapes participation, agency, and the learning experiences of

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students with disabilities. The study also shows that the integration of simple technologies such as sensor systems based on the Internet of Things in school agricultural activities can function as a learning medium that supports practice-based learning experiences while strengthening students' emotional and social engagement in the learning process. Therefore, this study offers a conceptual perspective that connects contextual pedagogy, the capability approach*,* and inclusive education practices within the context of rural special schools.

However, this study has several limitations that require attention. First, this study is a case study conducted in a single rural special school, which limits the generalizability of the findings to other school contexts. Second, the relatively short duration of the intervention limits the ability of the study to assess the long-term sustainability of the observed changes in students. Third, this study primarily examines changes at the pedagogical and psychosocial levels within the school environment and therefore cannot yet demonstrate direct impacts on broader social or economic empowerment. Therefore, future research should develop longitudinal research designs and involve a wider range of stakeholders, such as families, local communities, and rural economic networks, in order to understand how project-based learning practices can contribute more broadly to social inclusion and the strengthening of capacities among students with disabilities within community life.

REFERENCES

Ainscow, M. (2020). Promoting inclusion and equity in education: lessons from international experiences. *Nordic Journal of Studies in Educational Policy*, *6*(1), 7–16. https://doi.org/10.1080/20020317.2020.1729587

Anwar, M., & Johanson, G. (2015). Mobile phones and the well-being of blind micro-entrepreneurs in Indonesia. *Electronic Journal of Information Systems in Developing Countries*, *67*(1), 1–18. https://doi.org/10.1002/j.1681-4835.2015.tb00481.x

Badan Pusat Statistik. (2024). Potret Penyandang Disabilitas di Indonesia: Hasil Long Form SP2020. *Badan Pusat Statistik*. https://www.bps.go.id/id/publication/2024/12/20/43880dc0f8be5ab92199f8b9/potret-penyandang-disabilitas-di-indonesia--hasil-long-form-sp2020.html

Balafoutis, A. T., Evert, F. K. Van, & Fountas, S. (2020). Smart Farming Technology Trends: Economic and Environmental Effects, Labor Impact, and Adoption Readiness. *Agronomy*, *10*(5), 743. https://doi.org/10.3390/agronomy10050743

Bell, S. (2010). Project-Based Learning for the 21st Century: Skills for the Future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *83*(2), 39–43. https://doi.org/10.1080/00098650903505415

Bianchi, N., Lu, Y., & Song, H. (2022). The effect of computer-assisted learning on students' long-term development. *Journal of Development Economics*, *158*. https://doi.org/10.1016/j.jdeveco.2022.102919

Bjørnerås, A. B., Langørgen, E., Witsø, A. E., Kvam, L., Nolan, C., Leithaug, A., & Horghagen, S. (2024). Processes Empowering Disabled Students in the Co-Production of Inclusive Higher Education. *Social Sciences*, *13*(7), 345. https://doi.org/10.3390/socsci13070345

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Christiansen, L. B., Clausen, K., Smedegaard, S., & Skovgaard, T. (2021). A Qualitative Exploration of Implementation, Adaptation, and Sustainability of a School-Based Physical Activity

ISSN 2715-8071 (online)

Intervention: Move for Well-Being in School. *SAGE Open*, *11*(1). https://doi.org/10.1177/21582440211000053

Creswell. (2012). *Educational Research: Planning, Conducting and Evaluating Quantitative and Qualitative Research*. Prentice Hall Upper.

Dewi, S. F., Indrawadi, J., Yulika, F., & Saifullah, S. (2022). Conflict Resolution Education Design in Indonesia. *The International Journal of Interdisciplinary Educational Studies*, *17*(1), 39.

Fauziyah, N., Maruf, N., Wardana, D. J., Azis, F., Bahar, E. E., & Husniati, A. (2025). Evaluating Inclusive Education Initiatives in Indonesia: From Policy to Practice. *Educational Process International Journal*, *16*(1). https://doi.org/10.22521/edupij.2025.16.232

Fionita, W., & Nurjannah, E. (2024). Implementasi Pendidikan Inklusif Sebagai Perubahan Paradigma Pendidikan di Indonesia. *Jurnal Bintang Pendidikan Indonesia*, *2*(2), 302–311. https://doi.org/10.55606/jubpi.v2i2.2968

Florian, L. (2014). Reimagining Special Education: Why New Approaches are Needed. In S. Publications (Ed.), *The SAGE Handbook of Special Education: Two Volume Set* (2nd ed., pp. 9–22). SAGE Publications Ltd. https://doi.org/10.4135/9781446282236.n3

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, *74*(1), 59–109.

Goodley, D. (2016). *Disability studies: An Interdisciplinary Introduction* (2nd Editio). SAGE Publications.

Govindasamy, P., Abdullah, N. B., & Ibrahim, R. B. (2021). Importance of Entrepreneurship Skills Amongstudent with Learning Disabilities. *Proceedings of the 4th International Conference on Special Education (ICSE)*, *4*, 1–16.

Gruenewald, D. A. (2003). The Best of Both Worlds: A Critical Pedagogy of Place. *Educational Researcher*, *32*(4), 3–12. https://doi.org/10.3102/0013189X032004003

Handayani, S. M., Yeigh, T., Jacka, L., & Peddell, L. (2021). Developing a heutagogy approach to promoting teacher competencies in Indonesia. *Cypriot Journal of Educational Sciences*, *16*(3), 939–951. https://doi.org/10.18844/CJES.V16I3.5765

Hikmat. (2025). Inclusive Education and Social Justice : A Sociological Literature Review of Equity and Access in Learning Environments. *INFLUENCE: International Journal of Science Review*, *7*(1), 51–64.

Isnawati, D., Zakaria, R. A., & Pratomo, L. C. (2025). Barriers to Inclusion: Exploring the Root Causes of Inclusive Education Challenges in Indonesia. *Jurnal UNIK: Pendidikan Luar Biasa*, *10*(1), 57. https://doi.org/10.30870/unik.v10i1.32033

Kiettikunwong, N., Narot, P., Istiq'faroh, N., Setiawan, R., & Deeod, P. (2025). Development of 21st Century Skills via a Social Service Program at the Tertiary Education Level in Indonesia. *Journal of Ecohumanism*, *4*(1), 3309–3319. https://doi.org/10.62754/joe.v4i1.6150

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Kolb, D. A. (2013). *Experiential Learning : Experience As The Source Of Learning And Experiential learning: experience as the source of learning and development*. Prentice Hall.

Krajcik, J. S., & Czerniak, C. M. (2018). *Teaching Science in Elementary and Middle School* (5th ed.). Routledge. https://doi.org/10.4324/9781315205014

Kumar, P., L, Gurmessa Chala G, Y. K., Y, A. A., & Rabira Bekele L, D. A. H. (2025). *Disability and Development* (1st Editio). Lulu Publication.

Lave, J., & Wenger, E. (1991). *Situated Learning*. Cambridge University Press. https://doi.org/10.1017/CBO9780511815355

Leijen, Ä., Arcidiacono, F., & Baucal, A. (2021). The Dilemma of Inclusive Education: Inclusion for Some or Inclusion for All. *Frontiers in Psychology*, *12*(September). https://doi.org/10.3389/fpsyg.2021.633066

ISSN 2715-8071 (online)

Limaj, E., & Bilali, E. (2018). Examining digital technology constraints on higher education in developing countries through the lens of the capability approach. *Proceedings of the 22nd Pacific Asia Conference on Information Systems - Opportunities and Challenges for the Digitized Society: Are We Ready?, PACIS 2018*.

Madushanki, A. A. R., Halgamuge, M. N., Wirasagoda, W. A. H. S., & Syed, A. (2019). Adoption of the Internet of Things (IoT) in Agriculture and Smart Farming towards Urban Greening: A Review. *International Journal of Advanced Computer Science and Applications*, *10*(4), 11–28. https://doi.org/10.14569/IJACSA.2019.0100402

Maufuriyah, I. (2018). Asia in Dynamism, Innovation, and Globalization Inclusive Support And Education Of Children With Special Needs; Issues, Challenges, And Responses. *The 6th Asian Academic Society International Conference (AASIC) A Transformative Community*, 247–257.

Miles, S., & Singal, N. (2010). The Education for All and inclusive education debate: conflict, contradiction or opportunity? *International Journal of Inclusive Education*, *14*(1), 1–15. https://doi.org/10.1080/13603110802265125

Mitchell, E. (2020). A qualitative exploration of family, work, community, and health service influences on hiv treatment uptake and adherence among female sex workers in three cities in Indonesia. *AIDS Education and Prevention*, *32*(3), 243–259. https://doi.org/10.1521/aeap.2020.32.3.243

Navarro, E., Costa, N., & Pereira, A. (2020). A Systematic Review of IoT Solutions for Smart Farming. *Sensors*, *20*(15), 4231. https://doi.org/10.3390/s20154231

Nilholm, C. (2021). Research about inclusive education in 2020 – How can we improve our theories in order to change practice? *European Journal of Special Needs Education*, *36*(3), 358–370. https://doi.org/10.1080/08856257.2020.1754547

Nussbaum, M. C. (2008). Creating Capabilities: The Human Development Approach and Its Implementation. *Hypatia*, *24*(3), 211–215. https://doi.org/10.1111/j.1527-2001.2009.01053.x

Odeh, K. B., & Lach, L. M. (2024). Barriers to, and facilitators of, education for children with disabilities worldwide: a descriptive review. *Frontiers in Public Health*, *11*(January). https://doi.org/10.3389/fpubh.2023.1294849

Palupi, F., & Budiyanto, C. W. (2019). TPS's role in participatory learning: Knowledge accumulative. *AIP Conference Proceedings*, *2194*. https://doi.org/10.1063/1.5139812

Pangestuti, R. D., & Pribadi, F. (2022). KONSTRUKSI SOSIAL PENDIDIKAN UMUM BAGI PENYANDANG DISABILITAS. *Jurnal Ilmiah Dinamika Sosial*, *6*(1), 37–48. https://doi.org/10.38043/jids.v6i1.3253

Purbasari, I., Yusuf, M., Marmoah, S., & Alali, A. A. (2025). Development of a community-based social collaborative e-learning model for adaptability of higher education students in Indonesia. *Frontiers in Education*, *10*. https://doi.org/10.3389/feduc.2025.1487484

Rahajeng, U. W., Hendriani, W., & Paramita, P. P. (2024). Navigating Higher Education Challenges: A Review of Strategies among Students with Disabilities in Indonesia. *Disabilities*, *4*(3), 678–695. https://doi.org/10.3390/disabilities4030042

Rahmawati, Y., Irwanto, I., Mardiah, A., Taylor, E., Taylor, P. C., Lisdiana, H., & Syaadah, R. S. (2025). Students' Engagement in STEAM PjBL-Design Thinking for Environmental Literacy. *Journal of Education Culture and Society*, *16*(1), 555–580. https://doi.org/10.15503/jecs2025.2.555.580

Rude, H., & Miller, K. J. (2018). Policy Challenges and Opportunities for Rural Special Education. *Rural Special Education Quarterly*, *37*(1), 21–29. https://doi.org/10.1177/8756870517748662

Sabela, P. T. (2023). Inclusive Education: Challenging Barriers, Claiming Human Rights and Social Justice. In *Using African Epistemologies in Shaping Inclusive Education Knowledge* (pp. 259–284). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-31115-4_15

ISSN 2715-8071 (online)

Sari, Z. P., Sarofah, R., & Fadli, Y. (2022). The Implementation of Inclusive Education in Indonesia: Challenges and Achievements. *Jurnal Public Policy*, *8*(4), 264. https://doi.org/10.35308/jpp.v8i4.5420

Shaeffer, S. (2019). Inclusive education: a prerequisite for equity and social justice. *Asia Pacific Education Review*, *20*(2), 181–192. https://doi.org/10.1007/s12564-019-09598-w

Shakespeare, T. (2014). *Disability Rights and Wrongs Revisited* (2nd Editio). Routledge.

Slee, R. (2011). *The Irregular School* (1th Editio). Routledge. https://doi.org/10.4324/9780203831564

Somad, A., Haryanto, S., & Darsinah, D. (2024). Inclusive Education for Special Needs Students in Indonesia: A Review of Policies, Practices and Challenges. *JMKSP (Jurnal Manajemen, Kepemimpinan, Dan Supervisi Pendidikan)*, *9*(2), 1024–1035. https://doi.org/10.31851/jmksp.v9i2.16192

Sumedi, G. R., Masrur, Muchamad Arifin, & Oman Sukmana. (2025). Power Relations in Inclusive Education: A Review of The Sociological Literature on Discriminatory Practices Against Children with Special Needs. *SOSIOEDUKASI : JURNAL ILMIAH ILMU PENDIDIKAN DAN SOSIAL*, *14*(2), 985–994. https://doi.org/10.36526/sosioedukasi.v14i1.5716

Sunardi, Yusuf, M., Gunarhadi, Priyono, & Yeager, J. L. (2011). The Implementation of Inclusive Education for Students with Special Needs in Indonesia. *Excellence in Higher Education*, *2*(1), 1–10. https://doi.org/10.5195/ehe.2011.27

Supriyanto, T., Hidayat, R., & Haryono, D. (2025). Pemberdayaan Penyandang Disabilitas. *Kaganga:Jurnal Pendidikan Sejarah Dan Riset Sosial Humaniora*, *8*(2), 143–153. https://doi.org/10.31539/kaganga.v8i2.14730

Taneja-Johansson, S., & Singal, N. (2025). Pathways to inclusive and equitable quality education for people with disabilities: cross-context conversations and mutual learning. *International Journal of Inclusive Education*, *29*(1), 1–16. https://doi.org/10.1080/13603116.2021.1965799

Thomas, J. W. (2000). *A Review of Research on Project-Based Learning*. The Autodesk Foundation.

Triyanto, Gunawati, D., Kurniawan, I. D., Hartanto, R. V. P., Rejekiningsih, T., Suryono, H., & Ariana, Y. (2023). Teachers' perspectives concerning students with disabilities in Indonesian inclusive schools. *Asia Pacific Education Review*, *24*(3), 291–301. https://doi.org/10.1007/s12564-022-09745-w

Tusianti, E., Paramartha, F. A. A. D. Y., Ikawati, D., Naviandi, U., Wahyuni, S., Handiyatmo, D., Trisnani, D., Dwi, A. N. A., Perwitasari, W. S., Padini, P. R. A., Ramadani, K. D., Rachmawati, Y., & Synthesa, P. (2023). *Analisis Tematik Kependudukan Indonesia Fertilitas Remaja, Kematian Maternal, Kematian Bayi, dan Penyandang Disabilitas*. Badan Pusat Statistik.

Waisath, W., McCormack, M., Stek, P., & Heymann, J. (2024). Dismantling barriers and advancing disability-inclusive education: an examination of national laws and policies across 193 countries. *International Journal of Inclusive Education*, *28*(10), 2088–2103. https://doi.org/10.1080/13603116.2022.2058623

Watts, T. W., Bailey, D. H., & Li, C. (2019). Aiming Further: Addressing the Need for High-Quality Longitudinal Research in Education. *Journal of Research on Educational Effectiveness*, *12*(4), 648–658. https://doi.org/10.1080/19345747.2019.1644692

Widjaja, G. (2025). Studi Komparatif Partisipasi Politik Penyandang Disabilitas di Berbagai Negara. *SIBATIK JOURNAL: Jurnal Ilmiah Bidang Sosial, Ekonomi, Budaya, Teknologi, Dan Pendidikan*, *4*(7), 1281–1290. https://doi.org/10.54443/sibatik.v4i7.2936

Wilson, A. K. (2025). *Identifying Perceived Barriers in Special Education*. Abilene Christian University.

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M.-J. (2017). Big Data in Smart Farming–A review. *Agricultural Systems*, *153*, 69–80. https://doi.org/10.1016/j.agsy.2017.01.023

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