STEM Integrated Vocational Program: Urgency in Improving the Comprehension Abilities of Students with Mild Intellectual Disability

Purnamawati[a], **Mumpuniarti**[b]
[ab]Universitas Negeri Yogyakarta, Indonesia
purnamawati.2022@student.uny.ac.id

Keywords:

vocational program; STEM; understanding abilities

program vokasional; STEM; kemampuan pemahaman

Abstract

Students with intellectual disabilities require special attention in learning to overcome conceptual and procedural challenges. This study aimed to examine the impact of a STEM-integrated vocational program on the comprehension abilities of students with mild intellectual disabilities. Using a quasi-experimental design, the research involved 50 purposively selected students at SLB Negeri Pembina Yogyakarta. The intervention group received STEM-integrated instruction, while the control group followed conventional vocational learning. The results indicated that although the proportion of students achieving scores above the Minimum Competency Criteria did not increase significantly, there was a significant improvement in comprehension abilities among the experimental group compared to the control group. These findings suggest that integrating STEM approaches into vocational education can effectively enhance comprehension skills, supporting more adaptive and inclusive learning outcomes for students with intellectual disabilities.

Siswa dengan disabilitas intelektual memerlukan perhatian khusus dalam belajar untuk mengatasi tantangan konseptual dan prosedural. Penelitian ini bertujuan untuk menguji dampak program kejuruan terintegrasi STEM terhadap kemampuan pemahaman siswa dengan disabilitas intelektual ringan. Menggunakan desain kuasi-eksperimental, penelitian ini melibatkan 50 siswa yang dipilih secara sengaja di SLB Negeri Pembina Yogyakarta. Kelompok intervensi menerima instruksi terintegrasi STEM, sementara kelompok kontrol mengikuti pembelajaran kejuruan konvensional. Hasilnya menunjukkan bahwa meskipun proporsi siswa yang mencapai skor di atas Kriteria Kompetensi Minimum tidak meningkat secara signifikan, ada peningkatan yang signifikan dalam kemampuan pemahaman di antara kelompok eksperimen dibandingkan dengan kelompok kontrol. Temuan ini menunjukkan bahwa mengintegrasikan pendekatan STEM ke dalam pendidikan kejuruan dapat secara efektif meningkatkan keterampilan pemahaman, mendukung hasil belajar yang lebih adaptif dan inklusif bagi siswa dengan disabilitas intelektual.

Journal of Disability Studies
INKLUSI
Vol. 12, No. 01, 2025
doi 10.14421/ijds.120206
Submitted: 16 Apr, 2025
Accepted: 14 Jul, 2025

A. Introduction

Vocational education for students with mild intellectual disabilities faces challenges that extend beyond mastering motor skills to include the development of conceptual understanding (Coñoman et al., 2024; Haber et al., 2016). The main issue lies in comprehension skills, including the capacity to internalize abstract principles, understand a causal relationship, and apply knowledge in new contexts (Mogensen et al., 2024). As a result, graduates of vocational programs often only perform tasks procedurally and repetitively but struggle to adapt when encountering problems or changes in the work environment (Savage & Candelaria, 2024). This condition does not indicate an inability to learn. Instead, it reflects specific cognitive characteristics that require pedagogical approaches fundamentally different from conventional methods.

Students with mild intellectual disabilities, typically with IQs ranging from 55 to 70, empirically exhibit numerous cognitive impairments that hinder the development of comprehension abilities (Orío-Aparicio et al., 2025; Spaniol & Danielsson, 2022). These impairments include difficulties with abstract thinking, short attention spans, and weaknesses in text-based learning. Such characteristics create significant barriers for processing information from standard instructional materials and necessitate intensive support as well as alternative visual-kinesthetic learning modalities (Alopoudi et al., 2023; Jung et al., 2025; Parks et al., 2022; Ponsford et al., 2023; Sarassanti et al., 2023; Wasfy et al., 2021).

The impact of these barriers in vocational education contexts is significant. Although students with mild intellectual disabilities are categorized as "learnable" and have the opportunity to achieve proficiency in semi-skilled occupations, many current vocational programs fail to build essential understanding (Ikutegbe et al., 2024; Whirley et al., 2020). This failure stems from the false assumption that repetitive teaching of procedural skills is sufficient (Herrick et al., 2022). s a result, students lack a conceptual framework that enables them to adapt, solve problems, and apply their skills flexibly in the evolving world of work (Zhao & Ko, 2024). Therefore, this paradigm must shift from merely attempting to correct deficiencies to designing instructional approaches that align with the cognitive profiles of students with mild intellectual disabilities.

Contextually, the paradigm shift in vocational education for students with disabilities in Indonesia is not merely a theoretical discourse but is supported by a robust and responsive policy framework. National regulations such as Law No. 8 of 2016 on Persons with Disabilities and Ministerial Regulation No. 70 of 2009 on Inclusive Education Implementation provide clear mandates for inclusive practices. Meanwhile, at the provincial level, the Special Region of Yogyakarta, the locus of this study, has gone a step further in formulating a particular and action-oriented policy on inclusive education. Meanwhile, the Special Region of Yogyakarta has further developed action-oriented policies to strengthen inclusive vocational education. Demographic data from the Yogyakarta Education, Youth, and Sports Office (DIKPORA) for the 2023/2024 academic year show that more than 1,400 students with intellectual disabilities are enrolled in senior and vocational high schools across the province. This significant population underscores the urgency of developing effective instructional models that respond to their unique learning needs.

Despite strong policies and a large student population, the facts reveal a significant gap between policy and practice. Many SLBs in Yogyakarta, such as SLB Negeri Pembina Yogyakarta, offer vocational skills programmes like culinary, fashion, information technology, workshop, and batik art (Mutiah, 2021). However, preliminary studies in the field show that implementing these programmes is often unplanned and unsystematic. The curriculum taught does not always meet the demands of the business and industrial world, and the resources available are often inadequate to facilitate learning. Furthermore, teachers' lack of self-efficacy and limited knowledge regarding the implementation of education for students with mild intellectual disabilities were also found (Kuyini et al., 2020). The integration of these findings will result in graduates who, although able to master a specific procedure, are still hampered by the fundamental problem of low comprehension skills. This will ultimately hinder students' ability to adapt and solve problems independently. This contradiction between ideal policy and problematic implementation underscores the urgent need for empirical studies to evaluate innovative instructional approaches capable of bridging this gap.

To bridge the gap between the potential of students with mild intellectual disabilities and the demands of the modern workplace, a relevant pedagogical breakthrough is necessary. This research proposes a vocational program integrated with the Science, Technology, Engineering, and Mathematics (STEM) approach as a strategic option. The STEM approach offers a mechanism to overcome the earlier cognitive barriers and transform vocational training from procedure-based to concept-based learning. STEM work patterns align closely with the learning profiles of students with mild intellectual disabilities (Meral et al., 2024). The primary methods are hands-on learning and project-based learning. This approach places students at the center of the problem and has relevance to everyday life. Such learning has also been shown to significantly increase student engagement, motivation, and attention span, which are key challenges in the learning of students with intellectual disabilities (Apanasionok et al., 2020). STEM practices systematically build higher-order thinking skills such as critical problem solving and creativity through collaborative activities (Hebebci & Usta, 2022). Furthermore, research demonstrates that this integrated approach improves conceptual understanding and numeracy literacy, even among students with intellectual disabilities (Muchyidin & Priatna, 2024). Therefore, integrating STEM in vocational programs promises to transform students from mere procedure implementers into adaptive and competent problem solvers.

While the argument for STEM-integrated vocational education is conceptually strong, a review of existing research reveals a significant gap. Studies have addressed the challenges of vocational education for students with mild disabilities, while others have documented the general benefits of STEM approaches for different types of disabilities (Ariza & Hernández, 2025). However, no study has specifically examined a systematically integrated vocational education program employing a STEM approach for students with mild intellectual disabilities. Therefore, this study aims to fill that gap by evaluating whether STEM-integrated vocational education can enhance procedural skills and comprehension, adaptability, and problem-solving abilities. Ultimately, the research seeks to provide empirical evidence on the effectiveness of this approach in aligning students' learning potential with workplace demands and supporting their independence.

B. Research Methods

1. Research Design

The study employed a quasi-experimental design with a pretest-posttest non-equivalent control group. This design was selected because it enables examining causal relationships between intervention and outcomes in authentic educational contexts, where randomization is often impractical or unethical in special education settings (Hayes et al., 2015). A methodological framework (Shadish et al., 2004) was used to address ambiguity in causal direction. While this design increases external validity due to the real-world setting, it also introduces threats to internal validity, such as selection bias. Therefore, researchers compared the groups' pretest scores and implemented procedures to control for potential threats, including maturation, history, and testing effects (Denny et al., 2023).

Table 1
Pretest-Posttest Nonequivalent Control Group Research Design

Group	Pretest	Treatment	Posttest
Experimental Group (A)	OA1	STEM Integrated Vocational Program (X)	OA2
Control Group (B)	OA3	Conventional Vocational Program	OB4

Source: Adapted from Shadish et al. (2004).

2. Research Participants

This study targeted all students with mild intellectual disabilities enrolled at SLB Negeri Pembina Yogyakarta in the 2023/2024 academic year (N = 102). A total of 50 students were selected and divided into two study groups. Since this study used established (fixed) classes, cluster purposive sampling was applied (Meral et al., 2022). In practice, the researcher purposively selected two classes with the most comparable initial academic and demographic characteristics, based on school administrative data and in-depth interviews with teachers and principals. All students in those classes were included in the study after the classes were selected. In situations where class dissolution for individual randomization is logistically and pedagogically infeasible, this approach is a practical and common strategy in educational research. The study must meet strict criteria to ensure a homogeneous sample and to reduce confounding variables. The inclusion and exclusion criteria are as follows:

- Inclusion Criteria: (1) Officially identified as having mild intellectual disabilities by the school psychologist; (2) Enrolled as active students in SMA/SMK at SLB Negeri Pembina Yogyakarta; (3) Aged between 15 and 18 years old.
- Exclusion Criteria: (1) Have less than 80% school attendance in the previous semester to ensure that the intervention is delivered consistently; or (2) Have sensory disabilities such as blindness, total deafness, or severe disruptive behaviour disorder.

Two groups were formed from the research sample (N=50), namely the experimental group (n=25) and the control group (n=25). Participants' demographic characteristics and pretest scores were analyzed to empirically examine the initial equivalence of the two groups and address any potential selection bias. The initial comparative data of the two groups are shown in Table 2.

Table 2
Demographic and Clinical Characteristics of Participants

Group	Experiment Group (n=25)	Control Group (n=25)	P value
Age (Mean, SD)	16 Years (1.2)	16 Years (1.4)	0.452*
Gender (M/F)	14 M /11 F	13 M/12 F	0.765*
IQ Score (Mean, SD)	63.5 (4.8)	64.1 (5.1)	0.689*
Comprehension Ability Pretest Score (Mean, SD)	55.2 (8.5)	54.8 (8.9)	0.873*

Source: Author's analysis (2025).

There were no statistically significant differences between the experimental and control groups regarding age, gender, IQ score, and comprehension ability pre-test score. Table 2 shows the results of the Mann-Whitney Test and Chi-Square Test analysis. These findings provide more substantial confidence that any differences observed post-test are more likely due to the intervention rather than baseline differences between groups.

3. Research Procedures

The study was carried out over eight weeks. In the first week, preparations involved obtaining permits, finalising measurement tools, and training observers. Participants were recruited during the second week, and baseline tests were conducted on both groups. The experimental group received a vocational programme incorporating STEM from the third to sixth weeks, while the control group followed a conventional vocational programme. All intervention activities were regularly supervised. Both groups completed post-intervention testing in the seventh week, and the research data were analysed in the eighth week.

This study involved an experimental group implementing a STEM-integrated vocational program in catering. The program shifted the learning method from procedural to a concept-based problem-solving approach. Students learn through science exploration, such as understanding chemical reactions in food ingredients, using technology with digital applications for recipes, engineering through cake mould modification, and mathematics in calculating costs and proportions of ingredients. In contrast, the control group followed a traditional vocational program focused on repetitive and procedural skills mastery without explicitly integrating STEM concepts.

4. Research Instruments

Comprehension Ability Test Instrument

The test instrument used to measure comprehension ability (dependent variable) was developed based on the Revised Taxonomy cognitive framework (Anderson & Krathwohl, 2001)This taxonomy was chosen because it provides a more dynamic decomposition of the thinking process using verbs and clearly distinguishes between the cognitive process dimension and the knowledge dimension. It is particularly suitable for measuring understanding in vocational contexts that require applying knowledge. The indicators in this test focus on the Understanding (C2) and Applying (C3) cognitive levels, which are at the core of functional comprehension skills.

Table 3
Lattice of Comprehension Ability Test Instrument

No.	Cognitive Process Dimension	Behavior Indicator	Item Number
1	Understanding - C2	Classify concepts based on their characteristics (examples and non-examples)	1,2
		Re-explain a procedure in their own words	3,4
		Interpret information from a diagram or a simple drawing	5,6
2	Applying - C3	Interpret information from a diagram or a simple drawing	7,8
		Implement a procedure in a new, slightly different context	9,10

Source: Author's development based on Anderson and Krathwohl (2001).

Observation Instrument for Implementation of STEM Integrated Vocational Program

Furthermore, as a basis for ensuring that the interventions were on target, an observation sheet was created based on the Conceptual Framework for Integrated STEM Education by Kelley & Knowles (2016). This framework was chosen because it fully explains the important components of authentic STEM learning, which focuses on solving real-world problems and incorporates various disciplines in a meaningful way.

Table 4
Lattice of STEM Observation Sheet

No	Key Component	Observation Indicator	Item Number
1	Situated Learning	Learning is contextualised in authentic problems relevant to students' lives	1
2	Engineering Design	Students engage in a design cycle (plan, try, test, refine) to create a solution.	2
3	Scientific Inquiry	Students conduct experiments or investigations to answer questions and draw evidence-based conclusions	3
4	Technological Literacy	Students use technology as an analysis or problem-solving tool (not just a presentation medium)	4
5	Mathematical Thinking	Students apply mathematical concepts (e.g., measurement, calculation) to analyze and make decisions	5

Source: Author's development based on Kelley and Knowles (2016).

Instrument Validity and Reliability

The validity of the measuring instrument was ensured through two stages. First, content validity was assessed based on the opinions of two experts in special education and vocational education. Second, construct validity was tested by giving the instrument to 30 students with similar characteristics but not included in the research sample group. Pearson's product-moment correlation analysis was used to determine each question's validity. The criteria for questions are considered valid if the calculated correlation value is greater than the table correlation value at the 5% significance level. All 10 questions in the instrument were declared valid. Meanwhile, the reliability test to measure comprehension ability was conducted using Cronbach's Alpha coefficient. The result showed a Cronbach's Alpha value of 0.701, higher than the minimum limit of 0.60, so the instrument was considered reliable.

5. Data Analysis Technique

Quantitative data analysis in this study was conducted in several stages to test the formulated hypotheses. The first stage was a prerequisite analysis test, namely a test of data distribution normality. This normality test was performed using the Kolmogorov-Smirnov test to determine whether the pretest and posttest scores came from a normally distributed population. The test results showed that the data did not meet the normality assumption ($p < 0.05$), so the statistical approach used for hypothesis testing was non-parametric statistics (Rooij et al., 2016). Next, two hypothesis tests were conducted to evaluate the intervention's effectiveness. The Mann-Whitney U test was used to analyze whether there was a significant difference in achievement scores between the experimental and control groups. Additionally, the Binomial Test was applied to assess whether the proportion of students who achieved the Minimum Completion Criteria (MCC) after the treatment showed a statistically significant increase. The statistical data analysis process was conducted using the Statistical Package for the Social Sciences (SPSS) version 25 software, with a significance level (α) set at 0.05.

Prerequisite Test

A prerequisite test was conducted to assess the normality of pre- and post-test score distributions using the Kolmogorov-Smirnov test, appropriate for samples of N=50. The results indicated that the data were not normally distributed ($p < 0.05$). Consequently, non-parametric statistics were employed for hypothesis testing, as they do not require assumptions of normality.

Hypothesis Test

Binomial Test

The Binomial Test is a non-parametric procedure to determine whether the observed proportion of students achieving the minimum passing score of 75 significantly differs from the expected proportion by chance. This test assessed whether the intervention resulted in more students reaching mastery levels. The hypotheses tested were as follows:

H_0 (Null Hypothesis): The proportion of students in the experimental group achieving scores ≥75 after the intervention is not significantly different from the expected proportion by chance or pre-intervention.

H_1 (Alternative Hypothesis): The proportion of students in the experimental group achieving scores ≥75 after the intervention is significantly higher than expected.

Mann-Whitney Test

The Mann-Whitney U Test is a non-parametric alternative to the independent samples t-test. It compares the distribution of ranks between two independent groups. In this study, the Mann-Whitney Test was applied for two purposes. First, it tested pretest scores to verify baseline equivalence between the experimental and control groups, supporting internal validity. Second, it compared posttest scores to assess whether the STEM-integrated vocational program produced significantly different comprehension outcomes. The hypotheses tested were as follows:

H_0 (Null Hypothesis): There is no significant difference in the distribution of comprehension scores between the experimental and control groups.

H_1 (Alternative Hypothesis): There is a significant difference in the distribution of comprehension scores in the experimental group, which is significantly higher than in the control group.

C. Results and Discussion

1. Results

Instrument Validity

The analysis showed that all ten items had r-calculated values exceeding 0.361 (see Table 5), indicating that the instrument was valid for measuring comprehension ability.

Instrument Reliability

The reliability analysis showed a Cronbach’s Alpha of 0.701, exceeding the minimum acceptable threshold of 0.60, confirming the instrument's reliability (Table 6).

Table 5
Instrument Validity Test Result

Item Number	R Table	R Count	Validity Status
1	0.361	0.439	Valid
2	0.361	0.627	Valid
3	0.361	0.439	Valid
4	0.361	0.626	Valid
5	0.361	0.439	Valid
6	0.361	0.509	Valid
7	0.361	0.366	Valid
8	0.361	0.487	Valid
9	0.361	0.407	Valid
10	0.361	0.397	Valid

Source: Author's analysis (2025).

Table 6
Instrument Reliability Test Result

Variable	Alpha Cronbach's Threshold	Obtained Alpha Value	Description
Comprehension Ability	0.6	0.701	Reliable

Source: Author's analysis (2025).

Hypothesis Testing

Normality Test

A normality test was conducted to determine the distribution of comprehension scores. Given the sample size (N=50), the Kolmogorov-Smirnov test was chosen as the appropriate method. The results (Table 7) show a significance value of $p < 0.05$ for the pretest and posttest data, demonstrating that the data were not normally distributed. Consequently, parametric statistical tests (such as the t-test) were deemed unsuitable, and all hypothesis analyses were conducted using non-parametric procedures that do not require the assumption of normality.

Table 7
Normality Test Result

Tests of Normality			
	Statistic	df	Sig.
Pretest	0.183	50	0.000
Posttest	0.203	50	0.000

Source: Author's analysis (2025).

Mann-Whitney Test

The Mann-Whitney U test revealed a statistically significant difference in comprehension scores between the experimental and control groups ($p < .001$). Accordingly, the null hypothesis (H_0) was rejected. The Mean Rank comparison further supports this result, with the experimental group achieving a Mean Rank of 35.00, substantially higher than the control group's 16.00. These findings support the research hypothesis that the integrated STEM vocational program is more effective in enhancing comprehension abilities among students with mild intellectual disabilities than conventional teaching methods. This suggests that STEM-based interventions may represent a more effective pedagogical approach for this student population.

Table 8
Mann-Whitney Test Result

Mann-Whitney Test			
Treatment	**Group**	**Mean Rank**	**Sig.**
Pretest	Control	26.16	0.742
	Experiment	24.84	
Posttest	Control	16	0.000
	Experiment	35	

Source: Author's analysis (2025).

Binomial Test

A binomial test was conducted to evaluate whether the STEM program significantly increased the proportion of students achieving the minimum passing grade of 75. In the pretest, 3 of 25 students (12%) reached this threshold, increasing to 7 of 25 students (28%) after the intervention (Table 9). The null hypothesis stated that the post-intervention proportion was not significantly higher than expected under the null model. The test yielded a significance value of $p = 0.424$, indicating no significant difference. Therefore, H_0 could not be rejected. These findings suggest that although the program improved average scores (as evidenced by the Mann-Whitney test), its intensity was insufficient to enable most students to surpass the Minimum Competency Criteria.

Table 9
Binomial Test Result

Binomial Test			
Group	**Treatment**	**N**	**Sig.**
Control	*Pretest*	25	0.000
	Posttest	25	0.000
Experiment	*Pretest*	25	0.000
	Posttest	25	0.424

Source: Author's analysis (2025).

2. Discussion

a. STEM-integrated Vocational Program

The findings of this study present an instructive contrast: while the Mann-Whitney test shows a highly significant effect of the intervention ($p < 0.001$), the Binomial test shows insignificant results ($p = 0.424$). This contrast is not a limitation, but rather a key insight generated by the research. This phenomenon highlights the crucial distinction between relative progress (positive shifts across the entire group) and the achievement of absolute mastery (the ability to surpass a fixed standard threshold) (Horowitz, 2018). Although the STEM intervention led to significant relative progress, it did not substantially increase the proportion of students achieving absolute proficiency. To understand these dynamics, the Response to Intervention (RTI) framework offers a powerful analytical lens. RTI is a tiered model that categorizes interventions based on their intensity (Johnson, 2020).

The eight-week STEM program in this study can be viewed as a Tier 2 intervention, which provided targeted and more intensive support than regular classroom instruction (Tier 1). The success of the Mann-Whitney test shows that this Tier 2 intervention effectively improved the group's average comprehension, shifting most students to a higher level of understanding than the control group. However, the non-significance of the Binomial Test results suggests that this intervention has not yet achieved the intensity required for students with the most significant needs (Tier 3) (Clarke et al., 2020). Despite showing progress, these students have not yet received intervention of sufficient duration, frequency, and individualization to help them surpass the rigid MCC threshold (Gersten et al., 2020). These findings underscore that achieving mastery of standards requires interventions that are not only pedagogically effective but also sufficiently intensive and sustained.

The success demonstrated by the Mann-Whitney non-parametric test, which compares rankings between groups, effectively captures growth. This indicates that the STEM intervention successfully shifted the entire distribution of student abilities upward (Gersten et al., 2020). Students across all performance tiers—lower, middle, and upper ranks—showed measurable improvement. However, the Binomial Test, which assesses proportions against a fixed standard (passing/failing the MCC), addresses a different question: mastery. The non-significant results clearly show that while all students are moving forward, this progress is insufficient to push a significant number of the most disadvantaged students across the "absolute finish line" set. This represents the core of the educational challenge: an intervention may be highly effective in driving progress, but it may fail to close the mastery gap.

Translating these findings into practice requires a paradigm shift among educators and school administrators. Practically, a teacher who only sees an increase in class averages may perceive the intervention program as wholly successful. However, this research encourages teachers to act as "data detectives" in their classrooms, actively identifying students who, despite demonstrating relative growth, consistently fail to achieve minimum proficiency criteria. Continuing the same Tier 2 intervention is an inefficient strategy for these students. Instead, these findings provide evidence-based justification for schools to strategically allocate resources to build a robust Tier 3 support system, such as forming ultra-small learning groups, providing individual tutoring sessions with specialist teachers, or using adaptive instructional materials to address fundamental conceptual gaps.

b. STEM's Role in Stimulating Comprehension Skills

The STEM-integrated vocational program implemented in this study is a form of Project-Based Learning (PjBL). Students with mild intellectual disabilities often struggle with abstract thinking and text-based instruction; integrating STEM with PjBL offers a more effective learning alternative for developing comprehension skills (So et al., 2022). International studies have consistently shown that STEM enhances performance, motivation, self-efficacy, and collaboration skills among students with mild intellectual disabilities (Mcdaniel, 2024). Importantly, STEM also supports meaningful learning by connecting new knowledge with prior experience, enabling students to process concepts in concrete, accessible ways that align with their individual comprehension profiles (Himawan et al., 2024).

The STEM-integrated vocational program in this study was comprehensively implemented across all components. In the science domain, learning activities such as colour mixing experiments exemplify inquiry-based and experiential learning approaches (Sungur-Gul & Tasar, 2023). Applying this approach is crucial because it bridges manual tasks with cognitive processes, fostering deeper conceptual understanding for students with intellectual disabilities (Čipková et al., 2024). The implementation of this science concept is an example of visual kinesthetic learning that directly focuses on the key strengths of students with mild intellectual disabilities, who are often found to be more likely to have advantages in concrete and sensory information processing compared to text-based or purely auditory learning (Vavougios et al., 2016).

The learning implementation in this study succeeded in increasing students' enthusiasm through the integration of simple technology. However, the potential role of technology in this context can be much broader and aligned with global education trends. The application of modern tools such as Artificial Intelligence (AI), Augmented Reality (AR), and Virtual Reality (VR) offers significant opportunities to create more personalized learning experiences (Hopcan et al., 2021). A

https://doi.org/10.14421/ijds.120206

learning experience with adaptive AI can adjust the difficulty level of materials and provide real-time feedback tailored to each student's responses. It can also present content in multiple modalities to address the learning needs of students with mild intellectual disabilities (Habib et al., 2022). This approach is highly relevant because it allows students to learn at their own pace and receive the targeted support at the right time, thus enhancing engagement and comprehension (Farhah et al., 2025).

Another reflection of STEM activities in this study is the engineering component. The vocational learning program integrated equipment assembly as a sequential process. This activity went beyond using tools and served as an introduction to the engineering design process. As a result, the overall process became a framework for structured problem solving, including problem identification, solution planning, prototyping, testing, and evaluation (Nguyện et al., 2025). By engaging students in this cycle, students with mild intellectual disabilities developed systematic and logical thinking skills (Jimenez et al., 2025). Furthermore, this process significantly develops fundamental engineering skills, which are a key component associated with high-level comprehension skills (Yang et al., 2024).

Applying STEM in this context transforms mathematics into a functional tool relevant for solving real problems. In this type of learning, students with mild intellectual disabilities no longer ask when they will use mathematics, but instead apply it to planning material quantities, measuring dimensions, estimating time, and evaluating project outcomes (Dogru, 2022). These activities are based on applied mathematical reasoning. Through the use of mathematical concepts in meaningful, purposeful contexts, students not only learn basic skills but also progress toward understanding the rationale for applying mathematics (Schnepel & Aunio, 2022). This process serves as a bridge that supports deeper comprehension and more effective decision-making.

Based on the previous explanation, STEM-integrated vocational programs can improve the comprehension ability of students with mild intellectual disabilities. This is achieved by removing abstract learning barriers and creating cognitive pathways towards functional understanding (Syukri et al., 2018). Previously elusive concepts, such as cause-and-effect relationships and systematic thinking, are translated into tangible experiences. These experiences can be observed and processed through hands-on activities such as experiments and engineering design processes (Gillies, 2020). This approach aligns with students' visual-kinesthetic learning strengths. In this context, mathematics is no longer presented as an isolated theory but as a relevant and valuable tool for real tasks such as measurement and planning, helping students understand the "why" behind the "what" (Nguyen et al., 2024). This holistic approach, supported by technology's ability to personalize learning, helps students move beyond memorization to understanding how knowledge applies in meaningful contexts (Ahmed et al., 2025). Ultimately, this process enhances their decision-making skills and independence.

This study not only confirms the worldwide pedagogical trend towards a strengths-based approach but also contributes to the growing international evidence on the potential effectiveness of STEM projects for students with disabilities. Importantly, it helps fill a gap in the literature on the intersection of vocational education, STEM, and mild intellectual disabilities. It offers a pedagogical model that has been tested and may be applicable in diverse contexts. One significant contribution of this research is applying and validating this model within the context of vocational education in Indonesia, which remains underrepresented in the global literature. These results encourage educators and policymakers to shift their focus from achieving end products to assisting the process of conceptual growth, especially by implementing STEM pedagogy supported by adequate resources. This shift requires specialized teacher training to help students with special needs conduct inquiry and assessment systems that can use process progress as a legitimate learning indicator. However, there are important methodological limitations, such as the single-site design and small sample size, so generalizations should be made cautiously.

D. Conclusion

The main conclusion of this study is that the STEM-integrated vocational program has a significantly positive effect on the comprehension ability of students with mild intellectual disabilities. The Mann-Whitney U test results (p=0.000), showing a significant mean rank difference between the experimental group (35.00) and the control group (16.00) after the intervention, provide strong evidence for this impact. However, this finding should be interpreted alongside the Binomial Test results (p = 0.424), which indicate that while the program successfully promoted collective progress, it did not enable a significant proportion of students to surpass the MCC within the study period. These combined results suggest that STEM interventions effectively drive progress, but achieving absolute mastery standards is gradual. They also highlight that single-threshold evaluations may not adequately capture learning gains among students with disabilities.

This research demonstrates the need for a pedagogical and curricular paradigm shift in special education. Learning should move beyond procedural teaching to integrate STEM approaches within vocational programs. This method transforms vocational training into conceptual learning experiences that build problem-solving and adaptation skills essential for post-school success. This approach relies heavily on strategic policy support, especially regarding sharing sufficient resources and, most importantly, ongoing teacher professional development programs. Given this study’s limitations, including a single-site design and a small sample size, future research should use a mixed-methods design to obtain more qualitative information and conduct a long-term study to track the program's long-term impact on graduates' employment outcomes and self-reliance. Thus, this research will be able to build a more solid evidence base for the empowerment of students with intellectual disabilities.

E. Acknowledgement

The author would like to express her deepest gratitude to Universitas Negeri Yogyakarta for providing the guidance and facilities necessary to complete this research. The author also wishes to thank all parties who actively participated in the research process, including SLB Negeri Pembina Yogyakarta as the research site. Special appreciation is extended to the teachers and students involved in the study.

F. References

Ahmed, S., Rahman, Md. S., Kaiser, M. S., & Hosen, A. S. M. S. (2025). Advancing Personalized and Inclusive Education for Students with Disability Through Artificial Intelligence: Perspectives, Challenges, and Opportunities. *Digital*, *5*(2), 11. https://doi.org/10.3390/digital5020011

Alopoudi, A., Makri, M., Alişoğlu, B., Doğan, A., Imbesi, A., Karakoyun, M., Lacapelle, A., Roux, M. A. N., Pissa, A., & Tsolaki, M. (2023). A Protocol for the Development and Assessment of a Non-Pharmacological Intervention Designed to Improve Cognitive Skills of Adults with Intellectual Disabilities: A Mixed Method Design. *Journal of Multidisciplinary Healthcare*, *16*, 3215–3226. https://doi.org/10.2147/JMDH.S422859

Anderson, L. W., & Krathwohl, D. R. (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom’s Taxonomy of Educational Objectives.* (Allyn & Bacon, Eds.). Pearson Education Group.

Apanasionok, M. M., Neil, J., Watkins, R. C., Grindle, C. F., & Hastings, R. P. (2020). Teaching science to students with developmental disabilities using the Early Science curriculum. *Support for Learning*, *35*(4), 493–505. https://doi.org/10.1111/1467-9604.12329

Ariza, J. Á., & Hernández, C. (2025). A Systematic Literature Review of Research-based Interventions and Strategies for Students with Disabilities in STEM and STEAM Education. *International Journal of Science and Mathematics Education*. https://doi.org/10.1007/s10763-025-10544-z

Čipková, E., Fuchs, M., & Šmida, D. (2024). Effectiveness of Experiential Learning of Roma Pupils in Terms of Educational Results – A Case Study. *European Journal of Contemporary Education*, *13*(3), 491–504. https://doi.org/10.13187/ejced.2024.3.491

Clarke, B., Doabler, C. T., Turtura, J., Smolkowski, K., Kosty, D. B., Sutherland, M., Kurtz-Nelson, E., Fien, H., & Baker, S. K. (2020). Examining the efficacy of a kindergarten mathematics intervention by group size and initial skill: Implications for practice and policy. *Elementary School Journal*, *121*(1), 125–153. https://doi.org/10.1086/710041

Coñoman, G. I., Clemente, V. A., & Carmona, C. (2024). Initiatives to support the school-to-work transition of people with intellectual disabilities: a systematic review. *Journal of Intellectual & Developmental Disability*, *49*(4), 488–500.

Denny, M., Denieffe, S., & O'Sullivan, K. (2023). *The Cambridge Handbook of Research Methods and Statistics for the Social and Behavioral Sciences* (A. L. Nichols & J. Edlund, Eds.). Cambridge University Press.

Dogru, M. S. (2022). Conceptual Knowledge, Experiences, and Sources of Information Secondary School Students Have about Owls. *Science Education International*, *33*(1), 50–55. https://doi.org/10.33828/sei.v33.i1.5

Farhah, N. S., Wadood, A., Alqarni, A. A., Uddin, M. I., & Aldhyani, T. H. H. (2025). Enhancing Adaptive Learning with Generative AI for Tailored Educational Support for Students with Disabilities. *Journal of Disability Research*, *4*(3). https://doi.org/10.57197/JDR-2025-0012

Gersten, R., Haymond, K., Newman-Gonchar, R., Dimino, J., & Jayanthi, M. (2020). Meta-Analysis of the Impact of Reading Interventions for Students in the Primary Grades. *Journal of Research on Educational Effectiveness*, *13*(2), 410–427.

Gillies, R. M. (2020). *Inquiry-Based Science Education*. CRC Press.

Haber, M. G., Mazzotti, V. L., Mustian, A. L., Rowe, D. A., Bartholomew, A. L., Test, D. W., & Fowler, C. H. (2016). What Works, When, for Whom, and With Whom: A Meta-Analytic Review of Predictors of Postsecondary Success for Students With Disabilities. *Review of Educational Research*, *86*(1), 123–162.

Habib, H., Abdul, S., Jelani, K., & Najla, S. (2022). Revolutionizing Inclusion: AI in Adaptive Learning for Students with Disabilities. In *Multidisciplinary Science Journal* (Vol. 01).

Hayes, J. A., Nelson, D. L. B., & Fauth, J. (2015). Countertransference in successful and unsuccessful cases of psychotherapy. *Psychotherapy*, *52*(1), 127–133.

Hebebci, M. T., & Usta, E. (2022). The Effects of Integrated STEM Education Practices on Problem Solving Skills, Scientific Creativity, and Critical Thinking Dispositions. *Participatory Educational Research*, *9*(6), 358–379. https://doi.org/10.17275/per.22.143.9.6

Herrick, S. J., Lu, W., Oursler, J., Beninato, J., Gbadamosi, S., Durante, A., & Meyers, E. (2022). Soft skills for success for job seekers with autism spectrum disorder. *Journal of Vocational Rehabilitation*, *57*(2), 113–126. https://doi.org/10.3233/JVR-221203

Himawan, S. B., Budiyanto, C. W., & Budianto, A. (2024). Technology Self-efficacy in Robotic-based Integrated STEM Learning: A Systematic Review. *Proceedings of the 6th Vocational Education International Conference (VEIC 2024)*, 135–142. https://doi.org/10.2991/978-2-38476-342-9_18

Hopcan, S., Polat, E., Ozturk, M. E., & Ozturk, L. (2021). Artificial intelligence in special education: a systematic review. *Interactive Learning Environments*, *31*(10), 7335–7353.

Horowitz, J. (2018). Relative Education and the Advantage of a College Degree: If Everyone Stands on Tiptoe, No One Sees Better. *Am Sociol Rev*, *83*(4), 771–801. https://doi.org/10.1177/0003122418785371

Ikutegbe, P., Randle, M., Sheridan, L., Gordon, R., & Dolnicar, S. (2024). Factors and key interactions influencing successful employment outcomes for people with disabilities. *Asia Pacific Journal of Human Resources*, *62*(1). https://doi.org/10.1111/1744-7941.12377

Jimenez, B., Wood, L., & Courtade, G. (2025). *Academics: STEM for Students with Intellectual Disability and Extensive Support Needs*. Springer, Cham.

Johnson, E. (2020). Response to Intervention. *Oxford Research Encyclopedia of Education*, *23*(1), 1123–1134.

Jung, J., Zhang, W., & Lee, M. (2025). The role of working memory and attention control in incidental L2 vocabulary learning from reading-while-listening. *International Journal of Applied Linguistics*, *176*(1), 44–75.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. In *International Journal of STEM Education* (Vol. 3, Issue 1). Springer. https://doi.org/10.1186/s40594-016-0046-z

Kuyini, A. B., Desai, I. (Ishwar), & Sharma, U. (2020). Teachers' self-efficacy beliefs, attitudes and concerns about implementing inclusive education in Ghana. *International Journal of Inclusive Education*, *24*(12), 1509–1526.

Mcdaniel, A. (2024). STEM Education for Students with Disabilities. In *American Journal of STEM Education: Issues and Perspectives* (Vol. 2).

Meral, M., Altun Yalcin, S., Çakir, Z., & Samur, E. (2022). Types of Sampling Methods in Human Research: Why, When and How? *European Researcher*, *13*(2). https://doi.org/10.13187/er.2022.2.55

Meral, M., Altun Yalçın, S., Çakır, Z., & Samur, E. (2024). The Effect of STEM-Based Robotic Coding Education on Primary School Students' Decision-Making Skills. *Kuramsal Eğitimbilim*, *17*(2), 478–498. https://doi.org/10.30831/akukeg.1355818

Mogensen, L. L., Drake, G., McDonald, J., & Sharp, N. (2024). Young people with intellectual disability speak out about life after school: "I want to do more in life than just…be a disability person." *Journal of Intellectual and Developmental Disability*, *49*(2), 121–133. https://doi.org/10.3109/13668250.2023.2245276

Muchyidin, A., & Priatna, N. (2024). Exploration of Mathematical Communication Skills of Students with Mild Intellectual Disability Through Manipulative Activities Using Bowls and Marbles. *Jurnal Matematika Kreatif-Inovatif*, *15*(2), 450–462.

Mutiah, K. N. (2021). Manejemen Pendidikan Keterampilan Vokasional Anak Tunagrahita. *Education for Exceptional Children*, *2*(1), 191–198. https://journal.upy.ac.id/index.php/PLB

Nguyen, H. T. M., Nguyen, G. T. C., Thai, L. T. H., Truong, D. T., & Nguyen, B. N. (2024). Teaching Mathematics Through Project-Based Learning in K-12 Schools: A Systematic Review of Current Practices, Barriers, and Future Developments. *TEM Journal*, *13*(3), 2054–2064. https://doi.org/10.18421/TEM133-33

Nguyện, L. C., Hoa, H. Q., & Hien, L. H. P. (2025). Integrating design thinking into STEM education: Enhancing problem-solving skills of high school students. *Eurasia Journal of Mathematics, Science and Technology Education*, *21*(4), 1–11. https://doi.org/10.29333/ejmste/16084

Orío-Aparicio, C., Bel-Fenellós, C., & López-Escribano, C. (2025). Understanding Adaptive Skills in Borderline Intellectual Functioning: A Systematic Review. In *European Journal of Investigation in Health, Psychology and Education* (Vol. 15, Issue 3). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/ejihpe15030040

Parks, K. M. A., Moreau, C. N., Hannah, K. E., Brainin, L., & Joanisse, M. F. (2022). The Task Matters: A Scoping Review on Reading Comprehension Abilities in ADHD. *Journal of Attention Disorders*, *26*(10), 1304–1324. https://doi.org/10.1177/10870547211068047

Ponsford, J., Velikonja, D., Janzen, S., Harnett, A., McIntyre, A., Wiseman-Hakes, C., Togher, L., Teasell, R., Kua, A., Patsakos, E., Welch-West, P., & Bayley, M. T. (2023). INCOG 2.0 Guidelines for Cognitive Rehabilitation Following Traumatic Brain Injury, Part II: Attention and Information Processing Speed. *Journal of Head Trauma Rehabilitation*, *38*(1), 38–51. https://doi.org/10.1097/HTR.0000000000000839

Rooij, I. J. M. de, Port, I. G. L. van de, & Meijer, J.-W. G. (2016). Effect of Virtual Reality Training on Balance and Gait Ability in Patients With Stroke: Systematic Review and Meta-Analysis. *Physical Therapy*, *96*(12), 1905–1918. https://doi.org/https://doi.org/10.2522/ptj.20160054

Sarassanti, Y., Hasmy, A., & Balkist, P. S. (2023). Diagnosis Kemampuan Mahasiswa Dalam Menyelesaikan Soal Permutasi Dan Kombinasi. *Jurnal Padegogik*, *6*(1), 44–53. https://doi.org/10.35974/jpd.v6i1.2964

Savage, M. N., & Candelaria, A. E. (2024). Healthy Nutrition for Adults With Intellectual Disability: Piloting a Mobile Health Application and Self-Management Intervention. *Intellectual and Developmen Disabilities*, *62*(2), 126–136.

Schnepel, S., & Aunio, P. (2022). A systematic review of mathematics interventions for primary school students with intellectual disabilities. *European Journal of Special Needs Education*, *37*(4), 663–678. https://doi.org/10.1080/08856257.2021.1943268

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2004). *Quasi-Experimental Designs for Generalized Causal Inference*. Houghton Mifflin.

So, W. W. M., He, Q., Chen, Y., Li, W. C., Cheng, I. N. Y., & Lee, T. T. H. (2022). Engaging Students with Intellectual Disability in Science, Technology, Engineering, and Mathematics Learning. *Science Education International*, *33*(1), 25–37. https://doi.org/10.33828/sei.v33.i1.3

Spaniol, M., & Danielsson, H. (2022). A meta-analysis of the executive function components inhibition, shifting, and attention in intellectual disabilities. In *Journal of Intellectual Disability Research* (Vol. 66, Issues 1–2, pp. 9–31). John Wiley and Sons Inc. https://doi.org/10.1111/jir.12878

Sungur-Gul, K., & Tasar, M. F. (2023). The Design, Implementation, and Evaluation of a STEM Education Course for Pre-Service Science Teachers. *Journal of Education in Science, Environment and Health*, 85–100. https://doi.org/10.55549/jeseh.1272793

Syukri, M., Soewarno, S., Halim, L., & Mohtar, L. E. (2018). The impact of engineering design process in teaching and learning to enhance students' science problem-solving skills. *Jurnal Pendidikan IPA Indonesia*, *7*(1), 66–75. https://doi.org/10.15294/jpii.v7i1.12297

Vavougios, D., Verevi, A., Papalexopoulos, P., Verevi, C.-I., & Panagopoulou, A. (2016). Teaching Science to Students with Learning and Other Disabilities: A Review of Topics and Subtopics Appearing in Experimental Research 1991-2015. *International Journal of Higher Education*, *5*(4). https://doi.org/10.5430/ijhe.v5n4p268

Wasfy, N. F., Abed, R. A. R., Gouda, E. M., Ghaly, M. S., & El-Wazir, Y. M. (2021). EFFECTIVENESS OF INSTRUCTIONAL DESIGN FRAMEWORK BASED ON COGNITIVE LOAD THEORY FOR CLINICAL SKILLS TRAINING. *Advanced Education*, *8*(18), 102–108. https://doi.org/10.20535/2410-8286.225686

Whirley, M. L., Gilson, C. B., & Gushanas, C. M. (2020). Postsecondary Education Programs on College Campuses Supporting Adults With Intellectual and Developmental Disabilities in the Literature: A Scoping Review. *Career Development and Transition for Exceptional Individuals*, *43*(4), 195–208.

Yang, W., Chookhampaeng, C., & Chano, J. (2024). Spatial Visualization Ability Assessment for Analyzing Differences and Exploring Influencing Factors: Literature Review with Bibliometrics and Experiment. *Indonesian Journal of Science and Technology*, *9*(1), 191–224. https://doi.org/10.17509/ijost.v9i1.66774

Zhao, Y., & Ko, J. (2024). Orchestrating vocational education classrooms for adaptive instruction and collaborative learning. *Cogent Education*, *11*(1). https://doi.org/10.1080/2331186X.2024.2351238