Effectiveness of a Training Program in Developing Scientific Concepts among Children with Intellectual Disabilities

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ABSTRACT

This study evaluates the effectiveness of a structured training program designed to enhance scientific concepts among children with mild intellectual disabilities. A quasi-experimental pre-test/post-test control group design was used with 20 children aged 6–9 years, recruited from special education centers. The experimental group received a training program focusing on four conceptual domains: human body, environmental concepts, living vs. non-living, and health and nutrition. Data were analyzed using paired t-tests, independent t-tests, effect size estimation, and the Friedman test. Results demonstrated significant improvements in the experimental group across all domains, with large effect sizes, while the control group showed no significant changes. Training session evaluations revealed consistent engagement across all observed skills. These findings support the integration of structured, evidence-based programs in special education settings to improve conceptual learning in children with intellectual disabilities.

Keywords: Intellectual disabilities; training program; scientific concepts; inclusive education; special education; child development.

INTRODUCTION

Intellectual disability (ID) is a developmental condition characterized by significant limitations in intellectual functioning and adaptive behavior, originating before the age of 18 (Schalock et al., 2010). These limitations frequently hinder the acquisition of academic knowledge, particularly in areas such as scientific concepts that require abstract reasoning and the integration of complex ideas. Children with ID often struggle with understanding basic scientific principles, which can negatively impact their academic progress and their ability to interact effectively within society (Emerson & Hatton, 2014).

Global education agendas, such as the UNESCO Education 2030 Incheon Declaration, emphasize the importance of inclusive and equitable quality education for all learners, including those with disabilities (UNESCO, 2015). Within this framework, special education has been recognized as a critical field for ensuring that children with ID receive tailored support to meet their learning needs. Research has demonstrated that structured training programs designed to address specific cognitive and developmental challenges can improve academic achievement, adaptive behavior, and social integration among children with disabilities (Eikeseth, 2004; Lovaas, 2007).

Despite these advances, there remains a gap in the literature concerning the teaching of scientific concepts to children with ID, particularly in developing countries. Most existing studies have focused on language, communication, and social skills, while fewer have examined conceptual learning in science. Scientific literacy is, however, essential for enabling children to understand their environment, make informed decisions about health and nutrition, and participate actively in their communities.

The present study addresses this gap by investigating the effectiveness of a training program specifically designed to enhance scientific concepts in children with mild intellectual disabilities. The program targeted four conceptual domains: Human Body, Environmental Concepts (plants and animals), Living vs. Non-Living, and Health and Nutrition. The study also examined children's engagement during training sessions to assess the feasibility and effectiveness of the intervention in real-world educational settings.

METHODS AND BACKGROUND

This study employed a quasi-experimental pre-test/post-test control group design to evaluate the effectiveness of a training program in developing scientific concepts among children with mild intellectual disabilities. The research design included both an experimental group, which received the intervention, and a control group, which did not.

Participants

The study sample consisted of 20 children (10 in the experimental group and 10 in the control group), aged between 6 and 9 years, diagnosed with mild intellectual disabilities (IQ range: 50–70). The participants were enrolled in special education centers. Children were matched for age and gender, and parental consent was obtained prior to inclusion in the study.

Intervention

The training program was designed to develop four key domains of scientific concepts: (1) Human Body Concepts, (2) Environmental Concepts (plants and animals), (3) Living vs. Non-Living Concepts, and (4) Health and Nutrition Concepts. The intervention was implemented over several weeks, with each session focusing on interactive, hands-on activities tailored to the developmental abilities of the children. Strategies included demonstrations, visual aids, repetition, group activities, and reinforcement.

Instruments

Two primary tools were used for data collection:

1. Scientific Concepts Assessment Scale: Developed by the researcher, this scale measured the children's understanding across the four conceptual domains, administered both before and after the intervention.
2. Training Session Evaluation Checklist: Used to assess children's engagement during each session, covering understanding, participation, interest, practical skill performance, and recall ability.

Data Analysis

Descriptive statistics (means, standard deviations, minimum, and maximum values) were computed for pre- and post-test scores. Inferential analyses included paired-sample t-tests (or Wilcoxon signed-rank tests when assumptions were not met) to evaluate within-group improvements, and independent-sample t-tests (or Mann–Whitney U tests) to compare post-test performance between the experimental and control groups. Effect sizes (Cohen's d) were calculated to measure the magnitude of improvements. The Friedman test was applied to session evaluation data to determine whether significant differences existed across engagement dimensions.

The study evaluated the effectiveness of a structured training program designed to improve scientific conceptual understanding among children with mild intellectual disabilities (ages 6–9). Participants were divided into two groups: experimental ($n = 10$) and control ($n = 10$). Four key domains were assessed: Human Body Concepts, Environmental Concepts (plants and animals), Living vs. Non-Living Concepts, and Health and Nutrition Concepts. Two main analyses were conducted: (1) Pre- vs. Post-test comparisons within each group, and (2) Post-test comparisons between groups. Additionally, effect size (Cohen's d) and engagement consistency (Friedman test) were calculated to evaluate the strength and reliability of outcomes.

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Equations Used

1. **Paired-sample t-test**

$$t = \frac{\bar{X}_{post} - \bar{X}_{pre}}{S_D/\sqrt{n}}$$

2. **Independent-sample t-test**

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

3. **Pooled standard deviation**

$$S_p = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}}$$

4. **Effect Size (Cohen's d)**

$$d = \frac{\bar{X}_{post} - \bar{X}_{pre}}{S_D}$$

5. **Friedman test (for engagement)**

$$\chi^2 = \frac{12}{n \cdot k(k+1)} \sum R_j^2 - 3n(k+1)$$

RESULTS

Table 1. Descriptive Statistics for Total Scores

Group	Mean (Pre)	SD (Pre)	Mean (Post)	SD (Post)
Experimental	7.5	1.27	13.8	2.39
Control	5.0	1.33	4.5	1.27

The experimental group showed a marked improvement (+6.3 points), indicating strong learning gains, while the control group showed no meaningful change. This suggests that the intervention had a substantial impact on learning outcomes.

Table 2. Inferential Statistics for Total Scores

Comparison	t	p	Effect Size (d)
Experimental (Pre vs Post)	11.28	< .001	3.57
Control (Pre vs Post)	-1.63	.138	—
Experimental vs Control (Post)	10.85	< .001	—

Paired t-tests revealed significant improvement in the experimental group ($p < .001$) but not in the control group ($p = .138$). An independent t-test confirmed a significant post-test difference between groups ($p < .001$). The large Cohen's d (3.57) indicates a very large effect size.

Table 3. Domain-Specific Results (Experimental vs Control)

Domain	Exp Pre	Exp Post	Ctrl Pre	Ctrl Post	t	p	Cohen's d
Human Body Concepts	3.0	4.6	2.3	2.4	6.00	< .001	1.90
Environmental Concepts	2.4	3.3	1.4	1.1	2.59	.029	0.82
Living vs Non-Living	0.6	1.9	0.4	0.4	6.09	< .001	1.93
Health & Nutrition	1.5	4.0	0.9	0.9	15.00	< .001	4.74

All domains showed statistically significant improvements ($p < .05$). The strongest gains were in Health & Nutrition ($d = 4.74$), followed by Living vs Non-Living and Human Body Concepts. The Environmental domain exhibited a moderate effect size ($d = 0.82$).

Table 4. Training Session Evaluation

Item	Mean	SD
Understanding of Basic Concepts	1.25	0.44
Participation in Activities	1.28	0.45
Interest and Interaction	1.33	0.47
Performance of Practical Skills	1.20	0.41
Memory and Recall Ability	1.35	0.48

The Friedman test ($\chi^2(4) = 3.46$, $p = .485$) indicated no significant difference across session evaluation items, suggesting that children were equally engaged throughout the training program.

DISCUSSION OF RESULTS

The results confirm that the structured training program significantly enhanced conceptual learning among children with intellectual disabilities. The large effect sizes and significant t-values demonstrate the robustness of the intervention. The strongest improvement occurred in Health and Nutrition Concepts, likely because these topics are closely tied to children's everyday experiences, making them easier to comprehend and retain.

The findings align with previous studies showing that structured, interactive, and multimodal teaching strategies can enhance learning outcomes (Eikeseth, 2004; Lovaas, 2007; Dawson et al., 2010). The consistent engagement observed across sessions also reflects the principles of Universal Design for Learning (UDL), which emphasize flexible teaching methods that meet diverse learner needs.

These findings suggest that structured educational programs can play a critical role in inclusive education by bridging conceptual and experiential learning. Future research should explore long-term retention and apply similar interventions across larger, more diverse samples to confirm these findings.

DISCUSSION

The results of this study demonstrate that the structured training program was highly effective in improving scientific concept acquisition among children with mild intellectual disabilities. The significant pre- to post-test gains observed in the experimental group across all four conceptual domains support the hypothesis that targeted educational interventions can enhance conceptual understanding when instruction is tailored to the developmental needs of learners. In contrast, the control group showed no significant changes, suggesting that regular instruction alone may be insufficient for promoting meaningful gains in this population.

The strongest improvement was recorded in the domain of Health and Nutrition Concepts, which showed the largest effect size (Cohen's $d = 4.74$). This may be attributed to the immediate relevance of health and nutrition topics to children's daily lives, making them easier to understand and retain. Similarly, significant improvements were also observed in Human Body Concepts and Living vs. Non-Living Concepts, indicating that children were able to grasp both concrete and semi-abstract ideas when presented through experiential and visual learning methods.

These findings are consistent with previous research on structured intervention approaches. For instance, Eikeseth (2004) and Lovaas (2007) found that intensive behavioral interventions could lead to significant cognitive and adaptive skill improvements in children with developmental disabilities. Similarly, Dawson et al. (2010) demonstrated that early intervention programs incorporating structured teaching and active engagement were effective in improving both social and cognitive development. The current study extends these findings to the domain of scientific learning, providing evidence that structured teaching methods can also support conceptual development among children with intellectual disabilities.

The results of the session evaluation analysis further support the effectiveness of the training approach. Children displayed consistent levels of engagement across all observed dimensions, including understanding, participation, interest, practical skills, and recall. The absence of significant variation between these dimensions (as shown by the Friedman test) suggests that the training program was balanced and effective in maintaining attention and motivation throughout. This aligns with the principles of universal design for learning (UDL), which advocate for varied instructional methods to sustain engagement and optimize learning outcomes.

From a practical standpoint, these findings underscore the importance of integrating structured, evidence-based programs into special education curricula. Educators should employ multimodal teaching strategies that combine visual, auditory, and kinesthetic learning components. Additionally, incorporating real-life examples and interactive activities can help bridge the gap between abstract scientific concepts and tangible experiences, enhancing comprehension.

The study also highlights the need for further research in this field. Future studies should explore longitudinal effects to determine the sustainability of these learning gains and whether similar improvements can be achieved across different age groups and cultural contexts. Furthermore, expanding sample sizes and including additional cognitive and behavioral outcome measures could provide a more comprehensive understanding of the program's impact.

CONCLUSION

This study aimed to evaluate the effectiveness of a structured training program designed to enhance the acquisition of scientific concepts among children with mild intellectual disabilities. The findings revealed significant improvements across all four conceptual domains—Human Body, Environmental Concepts, Living vs. Non-Living, and Health and Nutrition—among children in the experimental group, while the control group showed no notable changes. These results confirm that structured, interactive educational programs can substantially improve conceptual understanding in learners with developmental challenges.

The large effect sizes observed in this study, particularly in the Health and Nutrition domain, highlight the importance of using practical, relevant, and experience-based learning approaches. Concepts related to daily life and self-care appear to be more accessible to children with intellectual disabilities, emphasizing the value of linking academic content with real-world applications. The findings support prior research (Eikeseth, 2004; Lovaas, 2007; Dawson et al., 2010) that underscores the benefits of structured and evidence-based interventions for children with special needs.

From an educational perspective, these findings have several implications. Teachers and curriculum developers should integrate structured concept-training modules into special education programs to promote active learning, conceptual understanding, and adaptive skills. In addition, professional development for educators should focus on evidence-based instructional strategies that support cognitive engagement and foster inclusion within mainstream and special education environments.

At the policy level, the study reinforces the need for educational systems to adopt inclusive frameworks that provide equitable opportunities for children with disabilities. Governments and educational authorities should invest in training programs, assistive technologies, and adaptive curricula that promote learning for all students. Such initiatives would not only improve academic outcomes but also enhance social integration and quality of life for children with intellectual disabilities.

Future research should expand on these findings by investigating long-term effects of similar training programs, replicating the study with larger and more diverse samples, and comparing outcomes across cultural and educational contexts. Additionally, incorporating neurocognitive and behavioral measures could provide deeper insights into how structured learning interventions influence brain development and adaptive functioning.

In summary, the present study provides compelling evidence that structured, hands-on training programs are powerful tools for improving scientific understanding and overall educational outcomes in children with intellectual disabilities. By embracing evidence-based pedagogical practices, educators and policymakers can advance inclusive education and empower learners with intellectual challenges to reach their full potential.

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