The Impact of Differentiated Instruction on Tenth-Grade Students' Academic Achievement in Biology: A Quasi-Experimental Study in Jordan

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Abstract

This quasi-experimental study investigated the impact of Differentiated Instruction (DI) on the academic achievement of tenth-grade biology students in Jordan. A total of 84 students were randomly assigned to an experimental group (n=42) that received DI strategies tailored to diverse learning needs, and a control group (n=42) that followed traditional lecture-based methods. A teacher-trained 20-hour DI program was implemented over an 8-week intervention. Data were collected using a 40-item biology achievement test (Cronbach's $\alpha = 0.87$). Pre- and post-test results revealed a statistically significant improvement in the academic achievement of the experimental group compared to the control group ($p < .001$), with substantial effect sizes (Cohen's $d > 2.4$). An independent samples t-test confirmed no significant gender-based differences in achievement within the experimental group ($t(82) = 0.295$, $p = 0.769$). The findings suggest that DI is a highly effective and equitable pedagogical approach for enhancing learning outcomes in biology education. The study recommends integrating DI into science teacher training programs and curricula to cater to student diversity.

Keywords: differentiated instruction, academic achievement, biology education, secondary education, quasi-experimental study, Jordan

1. Introduction

Education serves as a fundamental pillar for cognitive and social development, with its effectiveness dependent on continuous pedagogical innovation. Traditional, one-size-fits-all teaching methodologies have faced extensive criticism for their failure to address the diverse learning needs, readiness levels, and interests of students (Tomlinson, 2014). In response, Differentiated Instruction (DI) has emerged as a proactive, student-centered framework that enables educators to modify content, process, product, and the learning environment to maximize individual student growth and engagement (Bondie & Zusho, 2018).

The challenge of addressing learner diversity is particularly pronounced in science education within the Arab world. In Jordan, large class sizes and a standardized national curriculum often hinder the implementation of personalized learning approaches. Biology, a subject characterized by abstract concepts and complex systems, presents significant learning obstacles for many students. Passive learning models prevalent in Jordanian science classrooms have been associated with low achievement scores and declining interest in STEM fields, highlighting the urgent need for innovative, responsive teaching strategies.

Although DI offers a promising solution, its empirical validation within specific Jordanian contexts, particularly in tenth-grade biology classrooms, remains limited. This study aims to address this critical research gap by providing robust, experimental evidence on the efficacy of DI in enhancing academic achievement and promoting equity in Jordanian science education.

1.1 Research Objectives

This study aims to:

1. Assess the effect of differentiated instruction on the academic achievement of tenth-grade biology students.

2. Examine potential gender-based differences in academic achievement resulting from DI implementation.
3. Identify the most effective DI strategies for enhancing student learning in biology.

1.2 Research Hypotheses

- H1: Students taught using differentiated instruction strategies will demonstrate significantly higher academic achievement in biology than those taught through traditional methods.
- H2: There will be no significant difference in academic achievement between male and female students within the experimental group taught using DI.

1.3 Research Questions

This study sought to answer the following questions:

1. To what extent does differentiated instruction impact tenth-grade students' academic achievement in biology?
2. Are there significant gender differences in academic achievement among students taught using differentiated instruction?
3. What are the most effective DI strategies for enhancing biology learning outcomes?

2. Theoretical Framework

This study is grounded in an integrated theoretical framework combining Vygotsky's (1978) Sociocultural Theory, particularly the Zone of Proximal Development (ZPD), and Gardner's (1983) Theory of Multiple Intelligences.

2.1 Vygotsky's Zone of Proximal Development (ZPD)

Vygotsky's ZPD conceptualizes the gap between what a learner can accomplish independently and what they can achieve with expert guidance. This theory posits that optimal learning occurs through targeted instruction and scaffolding within this zone. In this study, the ZPD provides the theoretical foundation for DI strategies such as tiered assignments and flexible grouping. Diagnostic pre-assessments were employed to determine individual readiness levels, enabling the design of activities with varying complexity and the provision of strategic scaffolding, which was gradually withdrawn as student competence increased.

2.2 Gardner's Theory of Multiple Intelligences

Gardner's theory challenges the unitary view of intelligence by proposing multiple distinct intelligences (e.g., linguistic, logical-mathematical, spatial, kinesthetic). This paradigm acknowledges diverse cognitive strengths and learning preferences. In this study, the Multiple Intelligences theory informed DI through varied content delivery methods (multimedia, hands-on activities, texts), multiple assessment formats, flexible grouping based on learning preferences, and choice boards that allowed students to demonstrate understanding through their dominant intelligences.

The integration of these theories creates a comprehensive framework. Vygotsky's ZPD addresses the "readiness" component, ensuring an appropriate challenge level, while Gardner's Multiple Intelligences inform the "interest" and "learning profile" dimensions, providing multiple pathways for engaging with and mastering biological concepts.

2.3 Additional Theoretical Foundations

Beyond Vygotsky's sociocultural theory and Gardner's multiple intelligences, this study draws upon Bandura's (1997) social cognitive theory, particularly the concept of self-efficacy, which aligns with DI's goal of building student confidence through appropriately challenging tasks. Furthermore, Bruner's (1996) constructivist approach emphasizes that learning is an active process where learners construct new ideas—a principle that underpins DI's student-centered methodology.

The theoretical underpinnings of DI are further supported by contemporary research. Subban (2006) established the research basis for differentiated instruction, demonstrating its philosophical and psychological foundations. Tieso (2005) examined how grouping practices and curricular adjustments—core components of DI—significantly impact student achievement. These theoretical perspectives collectively support DI as a comprehensive approach addressing readiness, interest, and learning profiles (Tomlinson, 2014; Bondie & Zusho, 2018).

3. Literature Review

3.1 Empirical Evidence on DI in Science Education

International research provides substantial evidence supporting the efficacy of Differentiated Instruction. A

comprehensive meta-analysis by Santangelo and Tomlinson (2012) established that DI consistently yields positive effects on student achievement across various disciplines. This conclusion is reinforced by a systematic review conducted by Deunk et al. (2018), which confirmed the cognitive benefits of differentiation practices in primary education. In science-specific contexts, the positive impact of DI is equally evident. Al-Shehri (2020) reported that DI significantly improved achievement and critical thinking skills among sixth-grade science students. Similarly, Salar and Turgut (2021) found that DI combined with the 5E learning cycle enhanced physics understanding. Beyond these studies, Valiandes (2015) demonstrated that DI significantly promoted literacy and reading in mixed-ability classrooms, highlighting its role in fostering educational equity. Furthermore, Bertsos (2005) specifically investigated biology education and found that differentiated homework assignments effectively enhanced academic achievement.

3.2 DI in Arab Educational Contexts

Research on DI in the Arab world is gradually expanding but remains relatively scarce compared to international literature. The existing studies, however, predominantly report positive outcomes. Al-Zahrani (2021) in Saudi Arabia documented significant improvements in chemistry achievement following a DI intervention. In Jordan, Obeidat (2022) found that DI strategies enhanced critical thinking skills among students. A recent study by Selden and Sakulwongs (2024) also demonstrated the effectiveness of DI on science learning achievement for elementary students in a similar international context. While these findings are promising, a conspicuous gap persists in the Jordanian context regarding experimental, subject-specific studies at the secondary level, particularly in biology. This study directly addresses this void by providing quasi-experimental evidence on the effect of DI in tenth-grade biology classrooms.

4. Methodology

4.1 Research Design

This study employed a quasi-experimental pretest-posttest control group design.

4.2 Participants and Sampling Technique

The study involved 84 tenth-grade students (42 males, 42 females) from the Latin Patriarchate Mixed Schools in Jordan. A multi-stage random sampling technique was employed: the school was purposively selected due to its representative demographics, then four tenth-grade classes were randomly selected and assigned to experimental and control groups. Participants were randomly assigned to either the experimental group (n=42) or the control group (n=42). An independent samples t-test confirmed no significant difference in pre-test scores between the groups ($t(82) = 1.21$, $p = .231$), establishing initial equivalence.

4.3 Instruments

The primary instrument was a 40-item multiple-choice biology achievement test, developed based on the curriculum units covered during the intervention. The test was validated by a panel of three experts in science education (face and content validity). A pilot study with 30 students from a non-participating school established high reliability (Cronbach's $\alpha = 0.87$).

4.4 Intervention and Procedures

The study was conducted in three phases over 11 weeks:

Phase 1: Preparation (2 weeks)

The biology teacher received 20 hours of training on DI principles and strategies. Differentiated lesson plans and materials were developed.

Phase 2: Intervention (8 weeks)

The experimental group received DI for four 45-minute sessions per week, while the control group received traditional, lecture-based instruction covering identical content.

Implementation of Differentiated Instruction:

The DI intervention was implemented across three biology units:

- Unit 1: Cellular Structure and Function (2 weeks)
- Unit 2: Genetics and Heredity (3 weeks)
- Unit 3: Human Physiology (3 weeks)

Teacher Training and Preparation:

The biology teacher completed 20 hours of specialized DI training focusing on:

- Designing tiered assignments for mixed-ability classrooms
- Creating flexible grouping strategies
- Developing multiple assessment formats

Specific DI Strategies Employed:

1. Tiered Assignments (Genetics Unit Example):
    - Level 1: Basic Punnett square problems (remedial)
    - Level 2: Complex inheritance patterns (grade-level)
    - Level 3: Real-world genetic counseling scenarios (advanced)
2. Flexible Grouping Approaches:
    - Readiness-based groups for skill-building sessions
    - Interest-based groups for project work
    - Mixed-ability groups for peer tutoring
3. Varied Content Delivery:
    - Multimedia simulations, hands-on models, and modified texts
4. Choice Boards:
    - Students selected activities to demonstrate mastery (e.g., create a diagram, write a report, build a model)

Phase 3: Data Collection (1 week)

The post-test was administered to both groups.

4.5 Data Analysis

Data were analyzed using SPSS version 26. The analytical procedure included:

1. Descriptive statistics (means, standard deviations, gain scores)
2. Assumption testing (normality via Shapiro-Wilk, homogeneity of variance via Levene's test)
3. Inferential statistics (independent t-tests, ANCOVA with pre-test as covariate)
4. Effect size calculations using Cohen's d

A significance level of $\alpha = 0.05$ was established for all statistical tests.

4.6 Ethical Considerations

The study adhered to ethical principles in educational research:

- Informed consent was obtained from school administration and parents
- Student participation was voluntary
- Confidentiality of data was maintained throughout the study
- The control group received the DI intervention after the study concluded

5. Results

5.1 Preliminary Analysis and Descriptive Statistics

Preliminary analyses confirmed the validity of statistical assumptions. The Shapiro-Wilk test verified normal data distribution ($p > .05$), and Levene's test established homogeneity of variances between groups ($p > .05$). Baseline equivalence between experimental and control groups was confirmed through an independent samples t-test on pre-test scores ($t(82) = 1.21$, $p = .231$).

5.2 Academic Achievement Outcomes

The consolidated results presented in Table 1 provide a comprehensive overview of the intervention's impact. The experimental group demonstrated remarkable and statistically significant gains compared to the control group.

Table 1. Academic Achievement Results by Group and Gender

Group	Gender	N	Pre-test Mean	Post-test Mean	Mean Gain	p-value	Effect Size (Cohen's d)
Experimental	Male	42	42.15	79.70	37.55	<.001	2.45
Experimental	Female	42	41.85	80.62	38.77	<.001	2.58
Control	Male	42	39.20	46.30	7.10	.065	0.30
Control	Female	42	38.45	47.14	8.69	.024	0.37

An Analysis of Covariance (ANCOVA) revealed a statistically significant main effect of teaching method on post-test scores, $F(1, 81) = 385.74$, $p < .001$, with a very large effect size (partial $\eta^2 = 0.83$). This indicates that the differentiated instruction model accounted for 83% of the variance in post-test achievement, providing robust support for Hypothesis 1 (H1).

5.3 Analysis of Gender Differences

To address the second hypothesis concerning gender-based differences, an independent samples t-test was conducted on the post-test scores of the experimental group. The results showed no statistically significant difference in achievement between male ($M = 79.70$, $SD = 19.30$) and female ($M = 80.62$, $SD = 17.85$) students who experienced the DI intervention ($t(82) = 0.295$, $p = 0.769$), with a negligible effect size (Cohen's $d = 0.065$). This non-significant result confirms Hypothesis 2 (H2), demonstrating that the benefits of differentiated instruction were equitably distributed across genders.

6. Discussion

6.1 Interpretation of Key Findings

This study provides compelling evidence supporting the efficacy of Differentiated Instruction in enhancing academic achievement among tenth-grade biology students in Jordan. The experimental group's substantial mean gain of approximately 38 points, compared to a minimal 8-point gain in the control group, represents a nearly five-fold improvement in learning outcomes. This dramatic difference is further validated by the ANCOVA results, which attributed 83% of the variance in post-test scores to the teaching method, and the exceptionally large effect sizes ($d > 2.4$) that far exceed conventional thresholds for large effects. These findings align with the theoretical frameworks of Vygotsky (1978) and Gardner (1983), suggesting that instruction systematically tailored to students' readiness levels and diverse intelligences creates optimal conditions for learning. The results corroborate previous international research (Santangelo & Tomlinson, 2012; Deunk et al., 2018) and extend their applicability to the Jordanian educational context. The remarkable effect sizes ($d > 2.4$) observed in this study exceed those reported in similar regional studies (Al-Shehri, 2020; Al-Zahrani, 2021), suggesting that the comprehensive DI approach implemented here may be particularly effective in biology education.

6.2 DI as a Strategy for Educational Equity

A significant finding of this study is the absence of statistically significant gender-based differences in achievement within the experimental group. This outcome indicates that the DI framework successfully created an inclusive learning environment that mitigated potential gender disparities often reported in science education. By offering multiple pathways to access content, process information, and demonstrate understanding, DI effectively catered to the varied strengths and learning preferences of both male and female students equally. This positions DI not only as a tool for enhancing achievement but also as a powerful strategy for promoting equity in STEM education within the Jordanian context and similar educational environments. This finding is consistent with Valiandes (2015), who demonstrated that DI promotes educational equity in mixed-ability classrooms, and extends this evidence to gender equity in science education.

6.3 Theoretical and Practical Implications

Theoretically, these findings strongly support the integrated framework of Vygotsky's Zone of Proximal Development and Gardner's Theory of Multiple Intelligences. The success of tiered assignments and strategic scaffolding confirms the importance of targeting instruction within a student's ZPD, while the positive response to varied content delivery and choice boards validates the relevance of addressing multiple intelligences. These practical outcomes align with the recommendations of Bondie and Zusho (2018) for making differentiation practical through classroom routines, and demonstrate the feasibility of implementing these strategies in Jordanian schools as shown in Obeidat's (2022) work on critical thinking.

6.4 Limitations and Avenues for Future Research

Despite robust results, this study has certain limitations. The 8-week intervention period, while sufficient to demonstrate significant effects, does not provide data on long-term knowledge retention. Future research should employ longitudinal designs to assess the sustainability of these gains. Furthermore, the reliance on quantitative measures, though powerful for establishing cause and effect, limits understanding of qualitative shifts in student engagement, motivation, and classroom dynamics. A mixed-methods approach in future studies could yield richer insights into the mechanisms behind DI's effectiveness, exploring the lived experiences of both students and teachers. This recommendation echoes the approach taken by Salar and Turgut (2021), who combined DI with the 5E learning cycle to examine both achievement and self-efficacy outcomes.

7. Conclusion and Recommendations

This study provides quasi-experimental evidence that implementing Differentiated Instruction represents a powerful approach for transforming biology education in Jordan. Building on the foundational work of Tomlinson (2014) and recent regional studies (Al-Zahrani, 2021; Obeidat, 2022), this research demonstrates that DI not only significantly improves academic achievement but does so through an equitable framework that bridges potential gender gaps in science education.

Based on these findings, the following recommendations are made:

1. For Policymakers and Curriculum Developers: Integrate DI principles into the national science curriculum and teacher guidebooks to support differentiated practices.
2. For Teacher Training Institutions: Incorporate mandatory, practical training on DI strategies into pre-service and in-service teacher education programs.
3. For Practicing Teachers: Actively adopt and adapt DI strategies, beginning with tiered assignments and choice boards, to address the diverse needs of their students.
4. For Researchers: Conduct longitudinal studies to assess the long-term impact of DI and investigate its effectiveness across different subjects and grade levels within the Arab region.

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No additional data are available.