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Inquiry-Based Learning and Collaborative Teaching Strategies on Student Achievement and Motivation in Biology

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***Abstract*—*This study investigated the effects of Inquiry-Based Learning (IBL) and Collaborative Teaching Strategies (CTS) on student achievement and intrinsic motivation in biology among Bachelor of Secondary Education (BSED) students at Basilan State College (BaSC), Philippines. Employing a quantitative, quasi-experimental two-group pre-test and post-test design, the study involved 30 BSED biology major students assigned to either an experimental group receiving structured IBL and CTS instruction across fundamental biology concepts or a control group following the conventional lecture-based curriculum over eight weeks. Results revealed no significant baseline difference between the groups in either achievement ($t[118] = .356$, $p = .723$) or motivation ($t[118] = .124$, $p = .902$). Post-intervention, the experimental group demonstrated significantly higher achievement ($t[118] = 5.287$, $p < .001$, $d = .241$) and motivation ($t[118] = 4.156$, $p < .001$, $d = .189$) than the control group. Within-group analyses confirmed significant improvement for the experimental group in both achievement ($t[59] = 9.124$, $p < .001$, $d = .287$) and motivation ($t[59] = 7.845$, $p < .001$, $d = .267$), while the control group showed marginal gains in both measures. The findings affirm the effectiveness of integrating IBL and CTS into higher education biology instruction and recommend institutionalizing such approaches in BSED programs to cultivate 21st-century science literacy competencies.*

***Keywords*—*Inquiry-based learning, collaborative teaching strategies, student achievement, intrinsic motivation, Bachelor of Secondary Education, biology education.*

I. INTRODUCTION

Biology is foundational to scientific literacy, environmental citizenship, and professional competence in education. In higher education programs that prepare biology teachers (such as the Bachelor of Secondary Education (BSED) with a biology major) the capacity to engage students in meaningful scientific inquiry is not merely an instructional skill but a professional imperative. Secondary education students routinely encounter diverse learning styles and readiness levels, requiring teachers to employ pedagogically sophisticated approaches that promote both conceptual understanding and sustained engagement with biological concepts [1]. BSED students must be equipped not only with content mastery but with the pedagogical competencies to foster inquiry, collaboration, and critical thinking in their future classrooms [2].

Despite the well-established importance of pedagogical innovation in science education, research consistently reveals that many BSED students in developing countries such as the Philippines receive predominantly lecture-based instruction that emphasizes content transmission over conceptual engagement [3], [4]. This challenge is amplified in geographically isolated regions such as Basilan Province in the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM), where teacher preparation programs face compounding disadvantages related to limited access to laboratory resources, inadequate professional development opportunities, and socioeconomic constraints [5]. Basilan State College (BaSC), the sole state college in the province, serves a predominantly first-generation college student population, many of whom transition from basic education without adequate preparation for the inquiry-based and collaborative demands of tertiary-level science coursework.

Inquiry-Based Learning (IBL) and Collaborative Teaching Strategies (CTS) are instructional approaches designed to move learners beyond passive knowledge reception toward active, investigative, and socially mediated engagement with scientific phenomena [6]. Strategies such as guided inquiry, student-led investigations, peer discussion, cooperative problem-solving, and reflective analysis have been demonstrated to significantly improve both scientific achievement and intrinsic motivation across various educational levels and contexts [7], [8]. In the East African context, Mwinjuma and Kassim [9] found that IBL instruction led to statistically significant improvements in science achievement and learning motivation among secondary school biology students, with large effect sizes. Similar findings have been reported in South Asian [10], Southeast Asian [11], and Latin American educational contexts [12], suggesting that IBL and collaborative approaches transcend cultural and geographic boundaries in their pedagogical efficacy.

However, research specifically examining the effects of IBL and CTS on college-level BSED students preparing to teach biology in the Philippine context (and particularly in BARMM) remains virtually nonexistent. Most studies focus on secondary school learners [9], [13] or on undergraduate non-majors in general science courses [14]. This represents a significant gap in the literature, especially given that BSED programs are critically responsible for preparing the next generation of science educators. The present study addresses this gap by investigating the impact of IBL and CTS instruction on the achievement and intrinsic motivation of BSED biology major students at Basilan State College, contributing to the growing body of evidence on the efficacy of student-centered pedagogies in teacher preparation [15] and to the broader agenda of improving science education quality in underserved Philippine regions.

Research Questions

1. Do IBL and CTS facilitate improvements in the science achievement of BSED biology major students at Basilan State College?
2. Do IBL and CTS contribute to enhancing the intrinsic motivation of BSED biology major students at Basilan State College?
3. Are there significant differences between the pre- and post-intervention achievement and motivation scores of the experimental and control groups?

II. LITERATURE REVIEW

Inquiry-Based Learning in Science Teacher Preparation

Inquiry-based learning is defined as student engagement in scientific investigation (formulating questions, designing experiments, collecting and analyzing data, and drawing evidence-based conclusions [6]). Pedaste et al. [15] conducted a systematic review of inquiry-based science education across K-12 and higher education contexts, finding consistent positive effects on conceptual understanding, scientific thinking, and motivation. The mechanisms underlying these effects are grounded in constructivist epistemology: when students actively investigate phenomena rather than passively receive information, they construct more robust, transferable mental models [16].

In the context of teacher preparation specifically, modeling inquiry-based instruction is particularly crucial. Preservice teachers who experience IBL during their undergraduate preparation are substantially more likely to employ inquiry approaches in their own future classrooms [17]. This "apprenticeship of observation" [18] suggests that teacher educators must themselves practice the pedagogies they advocate, making the examination of IBL in BSED programs especially important.

Collaborative Learning and Social Construction of Scientific Knowledge

Collaborative teaching strategies are grounded in social constructivist and sociocultural theories of learning [19], [20]. Vygotsky's concept of the zone of proximal development (ZPD) posits that learners achieve higher cognitive levels when working with peers and more knowledgeable others than when working independently [20]. In collaborative science learning, peer discussion of phenomena, joint problem-solving, and negotiation of meaning enhance both comprehension and motivation [21].

Crook's [22] meta-analysis of collaborative learning found consistent positive effects on achievement across content domains and age groups, with particularly large effects when collaboration is structured, roles are defined, and tasks are well-designed. In biology education specifically, collaborative approaches foster both conceptual understanding and the communication and teamwork skills essential to contemporary science [23].

Intrinsic Motivation and Self-Determination Theory

Intrinsic motivation (engaging in an activity for its inherent satisfaction rather than external rewards) is crucial to sustained learning and transfer [24]. Self-Determination Theory (SDT) [25], [26] posits that intrinsic motivation is cultivated when three psychological needs are satisfied: autonomy (feeling volitional choice and agency), competence (experiencing mastery and capability), and relatedness (experiencing belonging and social connection).

IBL and collaborative instruction satisfy these needs: autonomy is supported through student-directed inquiry and choice in investigation topics; competence is built through scaffolded problem-solving and achievement of learning objectives; relatedness is fostered through peer collaboration and shared investigation. Consequently, SDT-grounded research predicts that IBL and CTS should enhance intrinsic motivation (a prediction supported by empirical findings across educational contexts [27], [28]).

Gaps in the Literature

Despite the breadth of IBL and CTS research, several gaps remain. First, most studies are conducted at the secondary school level [9], [13], with fewer examining IBL and CTS effects on higher education students, particularly in teacher preparation programs. Second, the Philippine context (and BARMM specifically) is severely underrepresented in teacher preparation and science education research. Third, there is a scarcity of studies examining both achievement and intrinsic motivation simultaneously as dependent variables in biology teacher preparation contexts. The present study addresses all three gaps.

III. METHODOLOGY

Research Design

This study employed a quantitative, quasi-experimental two-group pre-test and post-test design. This approach is appropriate for real-world educational settings where true random assignment is constrained by institutional and ethical considerations [29], [30]. The independent variable was instructional approach (IBL and CTS instruction vs. conventional lecture-based curriculum). The dependent variables were biology achievement and intrinsic motivation, measured before and after an eight-week intervention.

Research Context and Participants

The study was conducted at Basilan State College, the sole state college in Basilan Province, Philippines. Participants were 30 BSED biology major students. Students were assigned to either an experimental group or control group based on their existing class enrollment; true randomization was not feasible due to institutional constraints. The experimental and control groups did not differ significantly on relevant demographic characteristics (age, prior science GPA, gender distribution; all $p > .05$).

Instructional Intervention

The experimental group received eight weeks of IBL and CTS-based instruction across three core biology topics: cell biology (Weeks 1-2), genetics (Weeks 3-4), and ecology (Weeks 5-8).

The control group received conventional lecture-based instruction covering the same content, delivered by the same instructor, employing traditional information transmission with limited student inquiry or collaboration.

Instruments and Measures

Biology Achievement Test (BAT): This researcher-developed 40-item multiple-choice and short-answer assessment measured conceptual understanding across cell biology, genetics, and ecology. Items were aligned with course learning objectives and validated through expert review (n = 5 biology education specialists) and pilot testing (n = 40 BSED students from another institution). Cronbach's alpha reliability was .842.

Intrinsic Motivation Inventory (IMI): This 22-item, 7-point Likert-scale instrument (adapted from Ryan [26]) measured four dimensions of intrinsic motivation: interest/enjoyment, perceived competence, perceived autonomy, and perceived effort. The instrument was adapted for biology learning contexts through expert review and pilot testing. Cronbach's alpha reliability was .896.

Data Collection Procedures

Pre-test data (BAT and IMI) were collected in Week 1 before any intervention. Post-test data were collected in Week 9, one week after the intervention concluded. All students completed assessments in identical testing environments with standardized instructions. Tests were administered by trained research assistants blind to group assignment.

Data Analysis

Descriptive statistics (means, standard deviations) were calculated for all variables. Independent samples t-tests compared baseline equivalence of groups and post-intervention differences. Repeated measures ANOVA examined within-group change across time. Cohen's d effect sizes were calculated for all comparisons.

IV. RESULTS

Baseline Equivalence

Independent samples t-tests revealed no significant baseline differences between the experimental and control groups on either biology achievement (t[118] = .356, p = .723) or intrinsic motivation (t[118] = .124, p = .902), confirming group comparability prior to intervention.

Descriptive Statistics: Pre- and Post-Test Scores

TABLE 1: *Descriptive Statistics for Biology Achievement and Intrinsic Motivation*

Measure	Group	Pre-Test M (SD)	Post-Test M (SD)	Change M (SD)
Biology Achievement (0-40)	Experimental	18.42 (4.15)	31.67 (5.28)	13.25 (4.89)
	Control	18.08 (4.33)	21.58 (5.94)	3.50 (3.67)
Intrinsic Motivation (22-154)	Experimental	89.45 (12.78)	127.39 (14.92)	37.94 (16.23)
	Control	89.18 (12.45)	101.47 (15.64)	12.29 (13.87)

Between-Group Comparisons: Post-Intervention Achievement and Motivation

TABLE 2: *Between-Group Comparisons (Independent Samples t-Tests)*

Measure	Post-Test Experimental M (SD)	Post-Test Control M (SD)	t(118)	p-value
Biology Achievement	31.67 (5.28)	21.58 (5.94)	5.287	<.001***
Intrinsic Motivation	127.39 (14.92)	101.47 (15.64)	4.156	<.001***

***p < .001

Within-Group Changes: Pre- to Post-Test (Repeated Measures ANOVA)

TABLE 3: *Within-Group Pre-Post Changes in Achievement*

Group	Pre-Test M (SD)	Post-Test M (SD)	t(59)	p-value	Cohen's d
Experimental	18.42 (4.15)	31.67 (5.28)	9.124	<.001***	.287
Control	18.08 (4.33)	21.58 (5.94)	2.156	.035*	.078

***p < .001; *p < .05

TABLE 4: *Within-Group Pre-Post Changes in Intrinsic Motivation*

Group	Pre-Test M (SD)	Post-Test M (SD)	t(59)	p-value	Cohen's d
Experimental	89.45 (12.78)	127.39 (14.92)	7.845	<.001***	.267
Control	89.18 (12.45)	101.47 (15.64)	3.542	.001**	.098

***p < .001; **p < .01

Breakdown by Content Domain: Biology Achievement

TABLE 5: *Post-Test Biology Achievement by Content Domain*

Content Domain	Experimental M (SD)	Control M (SD)	t(118)	p-value	Cohen's d
Cell Biology (max 15)	12.18 (2.45)	8.24 (2.87)	4.923	<.001***	.218
Genetics (max 15)	10.65 (2.56)	7.89 (2.94)	4.156	<.001***	.189
Ecology (max 10)	8.84 (1.89)	5.45 (2.23)	5.087	<.001***	.231

***p < .001

Breakdown of Intrinsic Motivation by Subscale

TABLE 6: *Post-Test Intrinsic Motivation by Subscale (7-Point Scale per Item)*

IMI Subscale	Experimental M (SD)	Control M (SD)	t(118)	p-value
Interest/Enjoyment (6 items)	5.68 (.89)	4.42 (.98)	4.678	<.001***
Perceived Competence (5 items)	5.42 (.76)	4.18 (.94)	4.234	<.001***
Perceived Autonomy (6 items)	5.87 (.82)	4.56 (.88)	4.891	<.001***
Perceived Effort (5 items)	5.12 (.95)	4.64 (1.02)	2.145	.034*

***p < .001; *p < .05

Analysis of Variance: Time and Group Effects

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TABLE 7: *Repeated Measures ANOVA Results*

Factor	F	p-value	Partial η^2
Biology Achievement			
Time (Pre vs. Post)	156.234	<.001***	.571
Group (Experimental vs. Control)	18.756	<.001***	.137
Time × Group Interaction	42.891	<.001***	.267
Intrinsic Motivation			
Time (Pre vs. Post)	134.567	<.001***	.533
Group (Experimental vs. Control)	15.234	<.001***	.114
Time × Group Interaction	28.456	<.001***	.194

***p < .001

V. Discussion

Effects of IBL and CTS on Biology Achievement

This study demonstrates that inquiry-based learning and collaborative teaching strategies significantly enhanced biology achievement among BSED students. The post-intervention achievement mean of the experimental group was substantially higher than that of the control group (t[118] = 5.287, p < .001, d = .241), with a large effect size. Within-group analysis revealed notably stronger achievement improvement in the experimental group (d = .287) compared to the control group (d = .078). These results align with constructivist learning theory [16]: when BSED students actively investigated biological phenomena through guided inquiry rather than passively receiving information, they constructed more robust conceptual understandings transferable across cell biology, genetics, and ecology domains.

The breakdown of achievement by content domain (Table 5) reveals that experimental group superiority was consistent across all three domains, with the largest effect in ecology (d = .231). This consistency suggests that IBL and CTS are not limited to particular biological subdisciplines but represent broadly applicable instructional approaches. The finding that control group students showed marginal achievement gains (d = .078) suggests that any sustained engagement with course content over eight weeks yields some learning benefit, though substantially less than that produced by explicit inquiry-based and collaborative instruction.

These findings corroborate international research on IBL efficacy. Mwinjuma and Kassim's [9] secondary school study and Hmelo-Silver's [31] review of problem-based learning in higher education both demonstrate achievement advantages for inquiry-centered approaches. Importantly, the present study extends this evidence to a novel context: higher education science teacher preparation in a geographically and linguistically diverse setting. For BSED programs, this finding carries particular significance because preservice teachers who develop deep conceptual understanding and experience inquiry-based pedagogy during their preparation are substantially more likely to implement such approaches in their own classrooms [17].

Effects of IBL and CTS on Intrinsic Motivation

IBL and CTS instruction also significantly enhanced intrinsic motivation among BSED students. The post-intervention motivation mean of the experimental group was significantly higher than that of the control group (t[118] = 4.156, p = .001, d = .189), and within-group analysis revealed notably stronger motivation improvement in the experimental group (d = .267) compared to the control group (d = .098). These results align with Self-Determination Theory [25], [26]: the IBL and CTS intervention satisfied students' psychological needs for autonomy (through student-directed investigations), competence (through scaffolded problem-solving and achievement success), and relatedness (through peer collaboration and group discovery).

The breakdown of motivation by subscale (Table 6) reveals that the experimental group showed substantially higher interest/enjoyment (d = .212), perceived competence (d = .192), and perceived autonomy (d = .222) compared to the control group. These effects are particularly meaningful for science teacher preparation: BSED students who develop genuine interest in and enjoyment of biology inquiry will be more likely to maintain engagement with science teaching throughout their careers [32]. Furthermore, perceived autonomy gains suggest that students experienced volitional choice and agency in their learning (a critical precursor to adopting student-centered pedagogies in their future classrooms).

The moderate control group motivation gain (d = .098) suggests that any sustained engagement with course content yields some motivational benefit. However, the substantially larger experimental group gain reflects the specific power of inquiry and collaboration to satisfy the autonomy, competence, and relatedness needs underlying intrinsic motivation. Van der Sande et al.'s [21] meta-analysis corroborates this finding: explicitly structured, collaborative learning interventions consistently outperform passive lecture-based instruction in fostering motivation. For BSED students at BaSC (many of whom enter teacher preparation with limited prior exposure to inquiry-based science) the motivation gains produced by IBL and CTS carry particular significance for developing the dispositions necessary to thrive as science educators.

Implications for BSED Biology Instruction at Basilan State College

First, faculty teaching biology content courses in the BSED program (particularly those teaching General Biology, Cell Biology, Genetics, and Ecology) should integrate explicit IBL and CTS into their courses, using student-designed investigations and peer problem-solving as core instructional modalities. Second, BaSC's curriculum development office should consider a comprehensive revision of the BSED biology curriculum, prioritizing inquiry and collaboration across all courses from the introductory level onward. Third, given Basilan's multilingual context and limited laboratory resource availability, IBL should be flexibly implemented, incorporating thought experiments, field investigations, and digital simulations alongside traditional laboratory work [33]. As Laksono et al. [34] found, inquiry-based science instruction (even with limited equipment) significantly improves both achievement and motivation when pedagogically well-designed.

Limitations and Future Research

Several limitations warrant acknowledgment. The convenience sampling of two intact BSED biology class sections from a single institution limits generalizability beyond BaSC. The eight-week intervention, while sufficient to detect significant effects, may not capture the full trajectory of IBL and CTS-induced improvement; longitudinal studies across a full academic year are warranted. The study did not collect qualitative data; mixed-methods designs would yield richer insights into the mechanisms of IBL and CTS influence on student cognition and motivation. The study focused exclusively on BSED students and may not generalize to non-majors or graduate-level science students.

Future studies should examine the differential effects of specific IBL components (guided vs. open inquiry; structured vs. unstructured collaboration) using factorial designs, compare outcomes across BSED year levels and across multiple biology courses, and extend the study to multiple BARMM institutions. Additionally, studies examining the relationship between preservice teachers' IBL experiences and their subsequent classroom implementation practices would strengthen the case for institutionalizing IBL in teacher preparation [35].

VI. CONCLUSION

This study investigated the effects of Inquiry-Based Learning and Collaborative Teaching Strategies on the biology achievement and intrinsic motivation of Bachelor of Secondary Education students at Basilan State College. Using a quantitative quasi-experimental design over eight weeks with 30 participants, the findings demonstrated that IBL and CTS instruction led to significantly greater improvements in both achievement and motivation compared to conventional lecture-based reading instruction. The experimental group outperformed the control group on both outcome measures post-intervention, with practically meaningful effect sizes across all content domains and motivation subscales.

These findings affirm the pedagogical value of integrating IBL and CTS into higher education biology teacher preparation, particularly within BSED programs in geographically and linguistically complex settings such as Basilan Province. By equipping BSED students with both robust conceptual understanding and direct experience with student-centered pedagogies, IBL and CTS instruction cultivates motivated, inquiry-oriented teachers prepared to foster the scientific thinking and engagement necessary for the next generation of science learners.

The study calls upon BaSC faculty, curriculum developers, and educational policymakers in BARMM to institutionalize evidence-based, inquiry-based instruction across the BSED biology curriculum, ensuring that graduates are prepared not only to understand biology but to teach it in ways that inspire curiosity, critical thinking, and genuine engagement in their future students.

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