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ORIGINAL ARTICLE

Unlocking the Power of Togetherness: Exploring the Impact of Cooperative Learning on Peer Relationships, Academic Support, and Gains in Secondary School Biology in Gedeo Zone South Ethiopia

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ABSTRACT

The purpose of this study was to assess the relative effectiveness of cooperative learning (CL) strategies on learners' peer relatedness, academic support (AS), and learning gains in Biology. A quasi-experimental non-equivalent group pre-test post-test design was employed, involving a sample of 81 students. Both quantitative and qualitative data were collected, and analyses were conducted using t-tests, one-way MANOVA, bivariate correlation, and regression analysis. As anticipated, the t-test and MANOVA results revealed that participation in CL strategies had a moderate to substantial effect on the measured variables, with Partial $\eta 2$ values ranging from 0.471 to 0.722. In addition, regression analysis indicated that peer relationships and AS together accounted for 43.2% of the variance in overall learning gains. Qualitative findings highlighted significant challenges to the effective implementation of CL, including students' unfamiliarity with the method, resource constraints, and teacher resistance. The findings provide preliminary evidence that shifting classroom instruction from a content-centric approach to a learner-centered approach can enhance not only the quality of teaching but also the quality of learning and key indicators of student success.

KEY WORDS: Cooperative learning; learning gains; peer relationship; quasi-experimental design

INTRODUCTION

Background of the Study

In the ever-evolving landscape of education, enhancing the learning experience in secondary school Biology remains a top priority (Lord, 1994). Understanding the pivotal role of social dynamics and collaborative strategies, this study explores the transformative potential of cooperative learning (CL).

Researches indicated that peer relationships (PRS) play a crucial role in shaping students' academic engagement and success (Țepordei et al., 2023; Van Ryzin et al., 2020). The dynamics within peer groups can either enhance or impede the learning environment (Tafirenyika, 2021). In addition, academic support (AS) has been recognized as a crucial factor in students' achievement and motivation in biology (Pedersen and Digby, 2014). CL, which focuses on collaboration and the co-construction of knowledge, presents a promising approach to addressing these aspects.

Existing research emphasized a significant positive relationship between CL and better academic outcomes (Johnson et al., 2014). However, the precise effects on PRS and the extent of AS are nuanced aspects that require further investigation. Recent research has emphasized how CL enhances peer interaction and cultivates a supportive learning environment in science (Gillies, 2023). Moreover, recognizing and accommodating individual student needs and abilities within CL frameworks have been highlighted as crucial (Stiles, 2006).

Furthermore, it has been suggested that integrating CL strategies with technology-driven platforms could enhance peer collaboration and AS in science (Tsai et al., 2023). Thus, this study was designed to explore the detailed connections between CL, PRS, AS, and overall learning outcomes in secondary school Biology.

Theoretical Framework of the Study

The philosophical foundations for advocating the CL strategy stem from various epistemological and pedagogical perspectives, notably the concept of learning through action (Dewey, 1986), learning through social participation (Lave and Wenger, 1991), learning as an activity situated within environmental and cultural contexts (Vygotsky and Cole, 1978), and learning through engagements with other learners (Rogoff et al., 2001).

Rooted in social interdependence theory, which supports many CL practices in education (Johnson and Johnson, 1999), CL promotes positive interdependence among students, where individual success relies on the contribution of others (Johnson et al., 1998). CL, as an instructional approach, embodies this theory within educational settings (Baloche and Brody, 2017; Johnson and Johnson, 2008), creating structured opportunities for students to collaborate and engage in shared learning experiences (Sharan, 2010). According to social interdependence theory, cooperation enhances interpersonal relationships more effectively than competition or solitary work (Johnson and Johnson, 2009). This creates a platform for positive social interactions among peers and fosters the development of lasting relationships over time (Van Ryzin and Roseth, 2019). These positive PRS not only improve AS (Kawabata and Crick, 2015) but also are associated with higher academic performance (Makara, 2013; Linton et al., 2014), greater involvement and effort (Baumgardner, 2015), and increased learning gains and satisfaction (Tadesse et al., 2020).

Practical implementations of CL at both school and university levels are grounded in social interdependence theory (Johnson and Johnson, 1999). The close alignment of theory, research, and practical application gives CL a distinct edge. Consequently, many researchers in this field are motivated to incorporate this theory into their studies (Keramati & Gillies 2022). Therefore, this study was framed by the principles of social interdependence theory.

Rationale of the Problem

Exploring the transformative potential of active learning strategies, particularly cooperative leaning, in secondary school Biology education is a journey brimming with both challenges and opportunities. Insights from cognitive load theory (Paas et al., 2004) reveal that the effectiveness of these methods hinges on educators' skill in managing cognitive demands effectively. Furthermore, Tomlinson and Allan (2000) advocated for inclusive practices, stressing the need for customized support to cater to the diverse needs of students in CL environments. This emphasis on inclusivity is well-supported by technology integration (Johnson et al., 2014), which can enhance active learning by providing interactive tools and fostering collaborative experiences.

However, the journey to successful implementation is fraught with challenges. Studies by Geletu and Mekonnen (2019) and Teshager (2009) highlighted persistent issues in enhancing student engagement and outcomes despite ongoing efforts. Aimed these challenges, there is optimism. Van Ryzin and Roseth (2019) highlighted the promise of collaborative learning to enhance PRS, AS, and students' engagement. Yet, significant barriers remain, as Geletu (2021) noted, including restrictive school policies and limited resources. Local research by Belilew (2015), Geletu and Mihiretie (2022), Habtewold and Bezabih (2019), and Molla and Muche (2018) highlighted the persistent challenges educators face, from limited awareness to political ideologies.

Despite the obstacles, the promise of CL to improve PRS, strengthen AS, and drive meaningful learning gains is powerful. Addressing these barriers is essential for fully realizing the benefits of active learning and advancing the future of Biology education.

This study aimed to evaluate how CL strategies affect PRS, AS, and learning outcomes in Biology at secondary schools in Gedeo Zone, South Ethiopia.

Objectives of the Study

The primary goal of this study was to assess the impact of CL on various educational outcomes in secondary school biology. Specifically, the study aimed to:

- Evaluate the impact of CL strategies on PRS, AS, and learning gains in biology.
- Identify and analyze local constraints in implementing CL strategies in secondary school class rooms by exploring participants' perception and feedback.
- Gather and analyze suggestions for improving the implementation of CL strategies based on participants' experience and observations.

Hypothesis

Aligned with the research questions, this study posed the following hypotheses.

H1: CL, compared to lecture-based instruction, will be associated with higher levels of PRS, greater AS, and increased learning gains in biology.

H2: Enhanced PRS and AS will be positively correlated with greater learning gains in biology.

Significance of the Study

This study is beneficial for demonstrating the effects of CL on PRS, AS, and gains in secondary school Biology. First, by examining the impact of CL on PRS, AS, and learning gains, the study would provide a deeper understanding of how collaborative pedagogical approaches can positively influence students' educational experiences and outcomes. This research could also serve as a practical guide for teachers, department heads, and school management bodies, offering evidence-based strategies for effectively implementing CL practices in biology lessons. In addition, the findings of this study would have the potential to inform future educational policies and practices, advocating for a shift from traditional teaching methods to CL approaches that prioritize students' engagement, collaboration, and academic achievement. Moreover, by acting as a valuable resource for future researchers, this study would contribute to the ongoing dialog on innovative teaching methodologies and their impact on student learning in secondary school Biology education.

Definitions of Operational Terms

CL is an instructional method in which a group of 5–6 heterogeneous students actively collaborate in a structured manner to achieve shared learning objectives, utilizing their diverse backgrounds and abilities to enhance their own and each other's understanding and mastery of the subject matter. Academic achievement refers to the academic outcomes that demonstrate the extent to which a student has achieved their learning goals. Peer relatedness encompasses the feeling derived from positive peer interactions with classmates, including experiences of being accepted, supported, and valued, contributing to a sense of belonging and mutual respect among peers. AS comprises programs and strategies implemented by schools to enhance students' academic achievement, providing them with resources, assistance, and guidance. Learning gains represent the measure of academic growth or improvement; a student demonstrates from 1 year to the next, reflecting their progress in mastering content knowledge and skills over time.

RESEARCH METHODOLOGY

Research Design

Because it is hard to obtain complete control over variables, conducting a true experiment in the field of educational research is difficult, and randomization is not always a practical way to reduce program disruptions (Wodaj and Belay, 2021). As a result, this study used a quasi-experimental design, more precisely, the non-equivalent control group pre-test–post-test design. Investigating the connections between variables that the researcher can reasonably control is made possible by this research design (Fraenkel and Wallen, 2012). Rowe and Oltmann (2016) offer a direction on how to apply this method in educational research, and using this kind of design is in line with the suggestion made by Hodges et al. (2020). This helped the researcher to easily incorporate the intervention into the academic schedule. Quantitative and qualitative data were utilized to obtain a comprehensive understanding of the implementation process and the outcomes (Tadesse and Gillies, 2015).

Population and Sampling

The sample for this study consisted of grade nine students from two government secondary schools in the Gedeo Zone. The rationale behind initiating the implementation of CL at this specific grade level stems from the researcher's belief that introducing a cooperative work culture at this stage has the potential to cultivate teamwork and may play a pivotal role in enhancing future performance in national examinations.

The Gedeo Zone education department documented a total of 27 secondary schools (Gedeo Zone Education Department, 2023). To ensure precision in measurement and control, two schools were chosen through a simple random sampling method, following the recommendation of Namusoke and Rukundo, 2022. Thus, Kofe Secondary School, which has 41 students, was designated as the control school and Dilla Comprehensive Secondary School, which has 40 students, as the intervention school. To guarantee a fair and impartial distribution, the schools were divided into two groups at random: The intervention and the control groups. By taking a strategic approach, the study's results should be more dependable and the impact of CL in the chosen schools should be better understood.

Descriptions of the Experimental Interventions

This research used a jigsaw CL model, which is made up of five interconnected components, as described by Tadesse et al. (2021): (1) Placing a strong emphasis on students' learning and achievement of other outcomes; (2) building relationships; (3) developing students' capacities; (4) persevering with learning steps across different activities; and (5) offering support for the consistent application of the new strategy. Furthermore, cooperative frameworks that outlined how students collaborated and what their learning objectives were served as the foundation for the structuring of the learning process during the intervention period (Železnik Mežan et al., 2023).

Following these principles, a jigsaw CL model was implemented according to the intervention plan, which spanned 16 weeks from September 7, 2023, to January 7, 2024. The curriculum incorporated a 40-min lesson within three periods per week. To ensure diversity within the jigsaw groups, students' cumulative grade point average and gender were considered when assigning group members. Accordingly, the class was divided into small, heterogeneous groups of 5–6 students, referred to as the home group. The day's lesson was segmented and assigned to each home group, where students collaborated to work on their assigned segment, each becoming the "expert" in that segment. Subsequently, the groups were reorganized, and each member joined a new group (an expert group) to present their segment and learn about others'. The experts then returned to their original group (the home group) to discuss all the provided segments. Finally, the students' comprehension of the learning segments was assessed.

Pre-intervention

The biology teachers who participated in the intervention attended a 3-day training workshop before it started. Particularly, the workshop concentrated on different jigsaw CL strategy techniques. During the intervention period, teachers received training on how to divide up students into groups and assign tasks.

Instruments of Data Collection

Questionnaire

Throughout this investigation, instruments that have been modified were employed to gather data. A survey questionnaire with questions about PRS, AS, and learning gains was completed by the research participants, who were students, both before and after the intervention period. A quick synopsis of these measuring tools is provided in the section below.

Peer relationship

The relatedness scale questionnaire developed by Furrer and Skinner (2003) and further validated and used by Van Ryzin et al. (2020), it was used to assess learners' PRS. The peer relationship questionnaire had four items. The items were measured along a five-point Likert scale, ranging from strongly disagree to strongly agree. Items included "When I'm with my group members, I feel accepted" and "I feel safe when I am with my group members".

Academic Support

This was assessed using adapted version of Tadesse et al., 2018 student engagement scale. The AS scale has also four items. The items were measured along a five-point Likert scale, ranging from strongly disagree to strongly agree. The items included "Other students in this class want me to do my best schoolwork" and "In this class, other students like to help me learn".

Learning gain

This was also assessed using an adapted version of the Tadesse et al. (2018) student engagement scale. The learning gain scale includes five items, measured along a five-point Likert scale, ranging from very poor to very good. The items assess the extent to which the course has contributed to various aspects of learning and personal development. Sample items include "The course has improved my written and communication skills" and "The course has increased my confidence in tackling unfamiliar problems".

Validation of instruments

To ensure linguistic accuracy, the researcher translated the original questionnaires into Amharic and consulted language experts for review. A pilot study involving 20 secondary school students was then conducted to pinpoint any ambiguities or misunderstandings. Participants were given the translated questionnaire and an assessment tool, accompanied by an explanation of the pilot study's objectives. Their task was to assess the clarity of the questionnaire and recommend necessary improvements.

Assessing the psychometric properties of measurement instruments

The validity of both pre-test and post-test instruments was meticulously evaluated using Principal Component Analysis (PCA) with Varimax Rotation. The results of the Kaiser-Meyer-Olkin (KMO) test for the pre-test indicated a high level of sampling adequacy (KMO = 0.843), affirming its suitability for analysis. Furthermore, Bartlett's test of sphericity yielded significant correlations between items (χ^2 (78) = 449.669, p = 0.000), further validating the appropriateness of PCA. The three-component solution extracted during analysis explained a substantial portion of the variance, totaling 63.129%. Component one accounted for 41.723%, component two for 11.65%, and component three for 9.756%. Remarkably, all three components displayed eigenvalues exceeding 1, ranging from 1.268 to 5.424, solidifying their significance. In addition, reliability analysis through Cronbach's alpha coefficients showcased robust internal consistency, with an overall alpha coefficient of 0.873. The subscale alphas for PRS, AS, and learning gains were 0.764, 0.799, and 0.851, respectively, further reinforcing the reliability of the instruments.

Similar validation procedures were applied to the post-test instruments, with the KMO test yielding a commendable value of 0.877, indicative of strong sampling adequacy. Bartlett's test of sphericity again revealed significant correlations between items (χ^2 (78) = 465.18, p = 0.000), reinforcing the suitability for PCA. In alignment with the pre-test findings, the three-component solution for the post-test elucidated a substantial 64.882% of the variance. Component one contributed 45.075%, component two 10.596%, and component three 9.212%, with all three components exhibiting eigenvalues surpassing 1, ranging from 1.198 to 5.868. Reliability analysis for the post-test instruments revealed an impressive overall alpha coefficient of 0.896, underscoring the robustness of the instruments. Furthermore, subscale alphas for PRS, AS, and learning gains were 0.813, 0.794, and 0.845, respectively, providing further evidence of reliability.

The instrument's validation was further substantiated through confirmatory factor analysis (CFA) conducted using AMOS 23 software (Figures 1 and 2). The CFA results for the pre-test indicated a well-fitting model, with χ^2 = 77.582, df = 62, and χ^2/df = 1.251. Notably, the goodness-of-fit index (GFI) stood at 0.875, while the Tucker–Lewis Index (TLI) and Comparative Fit Index (CFI) demonstrated strong values of 0.951 and 0.961, respectively. In addition, the Standardized Root Mean square Residual (SRMR) and Root Mean-Square Error of Approximation (RMSEA) were 0.100 and 0.056, respectively,

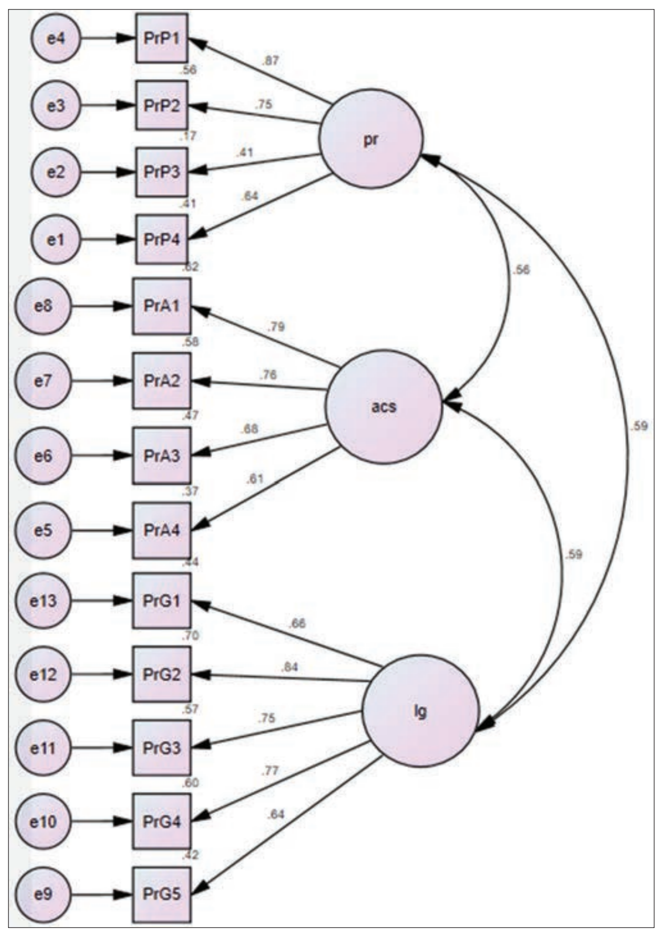

Figure 1: Path diagram illustrating the three-factor model for pre-test

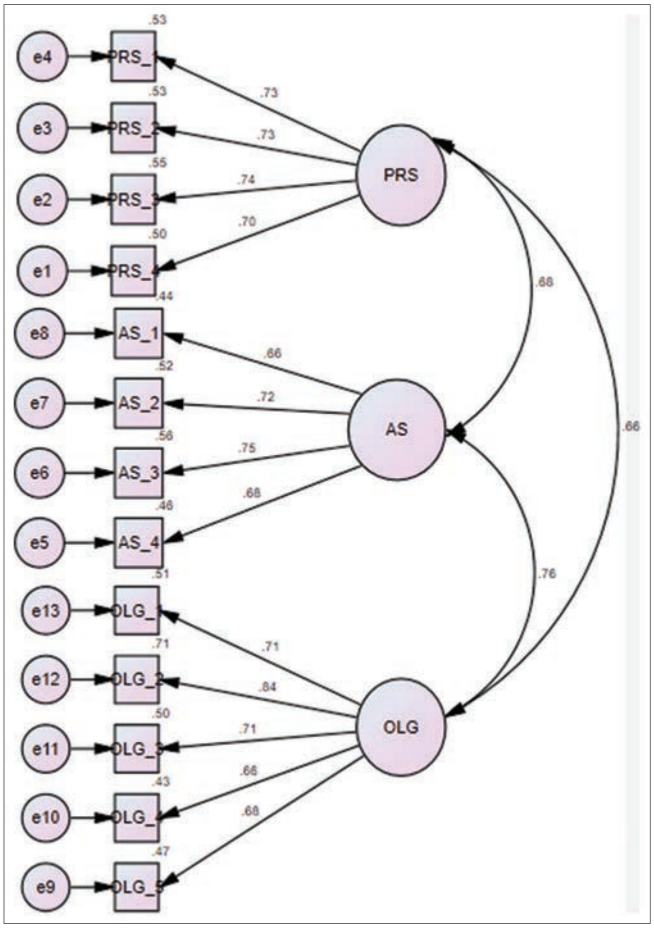

Figure 2: Path diagram illustrating the three-factor model for post-test

further affirming the model's adequacy. The Adjusted GFI (AGFI) capped off the robust fit indices at 0.817. Similarly, the CFA results for the post-test unveiled a model with strong fit indices, including $\chi^2 = 74.693$, df = 62, and $\chi^2/df = 1.205$. The GFI at 0.884, alongside the TLI and CFI values of 0.962 and 0.970, respectively, further bolstered confidence in the model's validity. Noteworthy were the SRMR of 0.074, RMSEA of 0.051, and AGFI of 0.830, collectively affirming the adequacy of the proposed model. Most researchers consider these values indicative of a good model fit (Brown, 2015; Collier, 2020; Kline, 2023).

Figure 1 presents the path diagram illustrating the pre-test relationships between the latent variables – PRS (pr), academic support (acs), and learning gains (lg), and their corresponding observed variables. The factor loadings range from 0.41 to 0.87, indicating moderate-to-high correlations. Error terms (e1-e13) represent the unexplained variance for each observed variable. In addition, the latent variables 'pr', 'acs', and 'lg' show correlations of 0.56–0.59, highlighting significant associations among these constructs in the pre-test results.

Figure 2 illustrates the path diagram representing the post-test relationships between the latent variables – PRS, AS, overall learning gains (OLG), and their respective observed variables. The factor loadings range from 0.66 to 0.86, indicating high correlations. Error terms (e1-e13) account for the unexplained variances in the observed variables. The latent variables PRS, AS, and OLG show correlations of 0.66–0.76, indicating significant associations between these constructs in the post-test results.

Interview

At the end of the intervention, 16 students from the experimental group (6 females and 10 males) volunteered for follow-up interviews. They were briefed about the study, and their consent was obtained to audio-record the sessions, with assurances given regarding the voluntary nature of their participation and their right to withdraw at any time without any consequences. Each interview lasted between 15 and 20 min and addressed several key themes: (1) their overall experience with the CL lessons, (2) strengths they identified in the CL approach, (3) specific examples illustrating these strengths, (4) the roles of the teacher and students in the CL lessons, (5) challenges faced, and (6) their overall feedback on the CL lessons. To ensure ethical integrity, responses were kept confidential, data were anonymized, and approval was obtained from the ethics committee of the College of Natural and Computational Sciences, Hawassa University, with the reference number CNCS-REC012/24.

Observation

Apart from conducting interviews, the experimental group's students' performances were also closely monitored. Over time, data were methodically gathered in a real classroom environment. For the CL class, a total of sixteen observation sessions were held. The observer was fully engrossed in carrying out CL in the classroom. Through firsthand observation of CL dynamics in action, the researcher obtained unique perspectives that are essential for understanding the results. The observer meticulously took notes to capture the essence of the class interactions during each 40-min observation session.

Data Analysis

In this study, bivariate correlation, one-way MANOVA, t-tests, and multiple regression analysis were used. PRS, AS, and OLG in biology were the three measured constructs used to determine how effective the CL approach was overall when compared to traditional lectures. The t-test and one-way MANOVA were used to analyze the data. All presumptions, including variance-covariance homogeneity, multivariate normality, and linearity, were examined before employing one-way MANOVA, and the data satisfied the presumptions. The relationships between the three dependent variables – PRS, AS, and overall biological learning gains – were investigated using bivariate correlation analysis.

Finally, the degree to which PRS and AS predict OLG in biology was investigated using multiple regression analysis. The appropriateness of the data was verified before regression analysis was performed. No outliers were discovered, and the dependent variable's distribution (the total amount of biology knowledge gained) was confirmed to be normal. The true distributional shape was assessed using histograms, and it was found that the scores were fairly normally distributed. An analysis of the typical Q-Q plot supported this as well. To determine the strength of the relationships between the independent variables, multicollinearity was tested using correlation analysis. Concern should be expressed about correlations that are 0.8 or 0.9 (Pallant, 2020). According to Pallant (2020), the correlation in this study between the two independent variables (AS and peer relationship) was r = 0.558, which is not a cause for concern. The tolerance and VIF values for the two variables were found to be 0.689 and 1.452, respectively. The results revealed that there was no problem of multicollinearity between the independent variables because the VIF is less than 10 and the CI is likewise less than 30 (Fidell, 2001). Simultaneously, considering the Durbin–Watson value (D-W = 1.708), it was confirmed that there was no autocorrelation (Fidell, 2001).

RESULTS

Demographic Characteristics of Participants

The findings presented in Table 1 indicate that a significant majority of the students, comprising 59 individuals (72.8%), were male, while the remaining 22 students (27.2%) were female. Regarding the age distribution of the participants, the largest portion of learners, 48 students (59.3%), was 16 years old, followed by 25 students (30.9%) at 15 years old, 7 students (8.6%) at 17 years old, and the remaining participant (1.2%) was 14 years old. The overall average mean for all participants was 15.75.

Summary Result of t-test before Intervention

The table presents the results of independent sample t-tests comparing the pre-test scores of the experimental and control groups before the intervention. For peer relationship, the experimental group mean was slightly higher (M_diff = 0.33) but not significantly different from the control group (t(79) = 1.544, p = 0.126). Similarly, there were no significant differences in AS (t(79) = 0.391, p = 0.697) or learning gains (t(79) = 0.556, p = 0.580) between the two groups (Table 2). These findings suggest that before the intervention, there were no baseline differences in the measured variables between the experimental and control groups.

Table 1: Sex and age of the participants

Sex of participants			
Details	**Frequency**	**Percent**	**Cumulative percent**
Male	59	72.8	72.8
Female	22	27.2	100
Total	81	100	
Age of participants			
14	1	1.2	1.2
15	25	30.9	32.1
16	48	59.3	91.4
17	7	8.6	100
Total	81	100	

Summary Results of t-test after Intervention

An independent sample t-test was conducted for the total sample (n = 81) as a preliminary analysis. As shown in Table 1, inspection of the two group means indicates that the average peer relationship score for the experimental group learners (4.58) is significantly higher than the control group learners' (3.20). The average AS score for experimental group learners (4.35) is significantly higher than the control group learners' (3.06), and the average learning gain score for the experimental group learners (4.25) is also significantly higher than the control group learners' (3.09). Experimental group learners were statistically significantly different from control group learners on peer relationship score (t(79)=14.334, p < 0.05), AS score (t(79)=8.395, p < 0.05), and learning gains score (t(79)=9.463, p < 0.05) (Table 3). In general, there is a higher score of learners in the intervention group than the traditional lecture group in measures.

The MANOVA revealed a significant multivariate main effect for pedagogic condition: Pillai's Trace = 0.838, F(3, 77) = 132.614, p < 0.05, partial eta squared = 0.838. Power to detect the effect was 1. Following the significance of the overall MANOVA test, the univariate main effect was examined. The result revealed that the effect is significant for peer relationship, F(1, 79) = 205.467, p < 0.05, partial eta square = 0.722, power = 1, AS, F (1, 79) = 70.408, p < 0.05, partial eta square = 0.471, power = 1, and OLG, F(1, 79) = 89.549, p < 0.05, partial eta square = 0.531, power = 1 (Table 4). Taken together, the t-tests and MANOVA results suggest that differences in pedagogical conditions did influence instructional processes and learning outcomes. Specifically, the results suggest that learners in the intervention group developed more PRS, supported each other, and developed more learning gains in the biology lesson compared to the control group learners.

Results of Correlation and Regression Analysis

As shown in the table above, the correlation analysis revealed strong positive associations among PRS, AS, and OLG. Specifically, the correlation coefficients were as follows: Peer relationship and AS (r = 0.558, p < 0.05), peer relationship and overall learning gain (r = 0.552, p < 0.05), and AS and overall learning gain (r = 0.604, p < 0.05) (Table 5). These results suggest that both PRS and AS positively contributed to learners' OLG.

As shown in the regression table above, the F value indicates that the multiple correlations R were significant (p < 0.05). That is, the contribution of all variables, PRS, and AS collectively significantly affected the OLG of learners in Biology. The t value indicates that the contribution of each variable, peer relationship, and AS significantly affected the OLG of learners in Biology lesson. From the regression table above, science R^2 = 0.432 for OLG in biology. Then, the two variables, peer relationship and AS, had a 43.2% effect or contribution on the overall learning gain in the Biology lesson (Table 6). The percentage of effect or contribution of each component, peer

Table 2: The t-test results of Peer relationship, Academic support, and learning gains between the experimental and control group participants before intervention

Factor	Experimental Groups (n=40)		Control Groups (n=41)		95% CI		Df	T	Sig. (2-tailed)
	M	SD	M	SD	LL	UL			
Peer relationship	3.70	0.92	3.37	0.98	−0.09	0.75	79	1.544	0.126
Academic Support	3.36	1.11	3.28	0.91	−0.36	0.53	79	0.391	0.697
Learning gains	3.55	0.98	3.43	8.89	−0.29	0.53	79	0.556	0.580

Table 3: The t-test results of peer relationship, academic support, and learning gains between the experimental and control group participants after intervention

Factor	Experimental Groups (n=40)		Control Groups (n=41)		95% CI		Df	T	Sig. (2-tailed)
	M	SD	M	SD	LL	UL			
Peer relationship	4.58	0.368	3.20	0.488	1.188	1.571	79	14.334	0.000
Academic support	4.35	0.476	3.06	0.844	0.978	1.587	79	8.395	0.000
Learning gains	4.25	0.512	3.09	0.585	0.913	1.400	79	9.463	0.000

Table 4: Summary results of the between subjects effects of the dependent measures between the intervention and control groups for the total sample

IV	DV	Type III sum of squares	Df	Mean square	F	Sig	Partial η^2
Design	Peer relationship	38.560	(1,79)	38.560	205.467	0.000	0.722
	Academic support	33.324	(1,79)	33.324	70.48	0.000	0.471
	Overall learning gains	27.124	(1,79)	27.124	89.549	0.000	0.531

Table 5: Relationships between peer relationship, academic support, and overall learning gain scores

Correlations	Post-peer relationship	Post-academic Support	Post-overall learning gains
Peer relationship			
Pearson Correlation	1	0.558**	0.552**
Sig. (two-tailed)		0.000	0.000
n	81	81	81
Academic support			
Pearson correlation	0.558**	1	0.604**
Sig. (two-tailed)	0.000		0.000
n	81	81	81
Overall learning gain			
Pearson Correlation	0.552**	0.604**	1
Sig. (two-tailed)	0.000	0.000	
n	81	81	81

**. Correlation is significant at the 0.01 level (two-tailed)

relationship, and AS on OLG in biology can be found by ($R^2 = \beta PRS \times rPRS + \beta AS \times rAS) \times 100$ (i.e., 43.2% = 17.22% + 25.97%). Therefore, the contribution of PRS enhanced the OLG in Biology by 17.22 and the contribution of AS enhanced the overall learning gain scores in Biology by 25.97%.

Results from Interview and Observation

In this study, the students' interview transcripts were organized into four major themes: (1) general perception of CL experience, (2) strengths of CL recognized by participants, (3) factors affecting effective implementation of CL, and (4) overall comments and suggestions regarding CL lesson.

General perception of CL experience

The majority of participants viewed CL positively. For instance, Participant 2 remarked, "At first, I was a bit skeptical about CL, but as we progressed, I realized how much I benefited from working with my peers. It helped me understand the material better." Another participant expressed happiness, stating "I found the CL experience to be really engaging. It differed from traditional lessons and made me feel more involved in my learning" (P1). Another female participant shared her enjoyment, saying, "I really enjoyed CL. It made learning feel less intimidating because I had support from my classmates, and I felt more confident in my abilities" (P3). Classroom observations also confirmed the positive perception of the method by the majority of learners.

Strengths of CL recognized by participants

The majority of the learners recognized various strengths of CL. For example, Participant 6 mentioned, "What stood out to me was how CL helped me build relationships with my peers. I felt like I got to know my classmates better, and it made the learning experience more enjoyable." Student 5 highlighted strength, stating, "One strength I noticed was how CL allowed us to learn from each other. We all had different perspectives and skills, so we could help each other out." In addition, Participant 4 noted, "I think one of the strengths of

Table 6: Multiple regression analysis with dependent variable – overall learning gains in biology and independent variables – peer relationship and academic support

Overall learning gain						
Multiple R=0.657 R^2=0.432						
ANOVA Table	**Sum of Squares**	**Df**	**Mean Square**	**F**		**p-value**
Regression	22.039	2	11.02	29.625		0.000
Residual	29.014	78	0.372			
Total	51.053	80				
Variables in the Equation						
Variables	**R**	**B**	**SE**	**β**	**t**	**p-value**
Peer relationship	0.552	0.305	0.101	0.312	3.032	0.003
Academic support	0.604	0.365	0.087	0.430	4.179	0.000

CL is that it promotes collaboration and teamwork. We had to communicate and work together to solve problems, which I believe is an important skill for the future."

Factors affecting effective implementation of CL

The interviewed participants highlighted several key factors for the effective implementation of CL in the classroom.

Participant 9 noted, "I noticed that in some lower classes, the lecture method was still being used extensively. This made it difficult to transition smoothly to CL, as some students were not accustomed to this approach. It created a disconnect in the learning process. Observations revealed that students' unfamiliarity with CL makes it difficult to effectively implement it. When students are ordered to discuss in groups, they were playing with each other rather than discussing the issue raised."

One factor that affected the effectiveness of CL for me was the shortage of textbooks. It was challenging to access the necessary resources, which hindered our ability to fully engage with the material (P7).

"I felt that the length of the period was a significant factor. Sometimes, there wasn't enough time to complete the CL activities thoroughly. We ended up feeling rushed, which impacted our learning experience," expressed participant 8. Observations supported the challenges mentioned by the participants. Sometimes, the period ended before reporting some group student's task.

"I believe there was a lack of alignment between the CL methodology and the political ideologies promoted within the school. This discrepancy created tension and resistance among some students, affecting the implementation of CL," remarked participant 10.

"I observed a significant barrier to effective implementation of CL, which was the lack of interest among the majority of teachers. It seemed like many teachers were reluctant to embrace CL methods and preferred traditional teaching approaches. This lack of interest from teachers made it challenging to fully integrate CL into our lessons and limited our opportunities for collaborative learning experiences," stated participant 11.

Furthermore, participant 12 said, "Another challenge we faced in implementing CL was the unsuitable classroom setup. The arrangement of chairs and desks was not conducive to conducting CL activities effectively. It was difficult for groups to collaborate comfortably, and the layout often hindered communication among peers. This inconvenience in the classroom setup posed a significant obstacle to the smooth execution of CL tasks."

According to participant 13, "An issue we encountered during CL sessions was the insufficient knowledge of the subject matter among some students. This lack of understanding often led to confusion and wasted our class time as we had to spend extra time explaining concepts to those who were struggling. It disrupted the flow of our CL activities and hindered our progress. Addressing this gap in knowledge became a significant challenge in effectively implementing CL in our classroom." The observer witnessed that low student knowledge about the subject matter was a major obstacle to discussion among the groups.

Overall comments and suggestions regarding CL lessons

Participant 16 suggests that students need to be introduced to CL pedagogies earlier in their educational journey. Providing orientation sessions or workshops on CL strategies at the beginning of the school year can familiarize students with the concepts and methodologies. This early exposure can better prepare them to actively participate in CL activities and maximize their learning potential.

Another suggestion is to embed CL activities in textbooks. By integrating these activities into the curriculum materials, students can easily access and engage with CL tasks during their regular study sessions. This ensures continuity and consistency in CL implementation across different subjects and topics (P15).

Furthermore, participant 14 suggests that it is important to provide more opportunities for engagement, especially for medium and low-ability students and silent listeners. Instead of relying solely on teacher-led instruction, incorporating CL activities allows these students to actively participate and contribute to the learning process. This fosters a more inclusive and collaborative classroom environment.

DISCUSSION

The current study provides compelling evidence that the jigsaw CL model effectively enhances learners' PRS, AS, and OLG in biology.

The t-tests indicated that learners in the intervention group scored significantly higher than those students who were in the control group across PRS, AS, and learning gains. This aligns with previous research that has shown the efficacy of interventions, such as collaborative learning environments or active learning strategies, in enhancing student outcomes (Freeman et al., 2014; Springer et al., 1999).

The MANOVA results supported the findings of the t-tests, indicating significant differences between the intervention and control groups across multiple outcome measures. This is consistent with literature suggesting that pedagogical approaches impact various aspects of student learning (Da Silva, 2008; Hattie, 2008; Slavin, 1996).

The regression analysis demonstrated that both PRS and AS had a significant contribution to OLG in biology. This finding underscores the importance of social interaction and support structures in educational settings (Tenenbaum et al., 2020; Wentzel, 1998).

The correlation analysis further confirms the positive associations between PRS, AS, and OLG. This aligns with previous research highlighting the role of peer interaction and support in fostering student achievement and engagement (Johnson and Johnson, 2009; Topping, 2013). Deci and Ryan, 2008 and Wentzel, 1998 also noted the significance of PRS and AS in shaping students' academic success and overall learning experiences.

Consistent with prior research, the results of the qualitative study showed that the majority of participants in this study expressed positive perceptions of CL, highlighting benefits such as improved understanding of material, increased engagement, and enhanced confidence. This aligns with the literature, which suggests that CL fosters active participation and social interaction among students, leading to improved academic outcomes (Johnson and Johnson, 1978; Slavin, 2014). Moreover, the identified strengths of CL, such as building relationships, learning from peers, and promoting collaboration, resonate with existing literature on the topic. For instance, Slavin (2014) emphasizes the importance of social relationships in CL settings, suggesting that positive interdependence among students leads to greater achievement and motivation.

Several factors affecting the effective implementation of CL emerged from the interviews and observations. These include students' unfamiliarity with CL, resource constraints, time limitations, ideological discrepancies, teacher resistance, classroom setup issues, and varying levels of student subject knowledge. The challenges related to student unfamiliarity with CL and inadequate resources are consistent with previous studies (Miles and Stipek, 2006). For instance, Miles and Stipek (2006) found out that students may initially struggle with CL due to a lack of familiarity with collaborative learning strategies. Similarly, the issue of time constraints resonates with research indicating that inadequate time allocation can hinder the depth and effectiveness of CL activities (Topping, 2005). In addition, the challenges posed by ideological discrepancies and teacher resistance highlight the importance of addressing institutional and attitudinal barriers to CL implementation (Hattie, 2008). The observations regarding classroom setup and student subject knowledge echo previous findings on environmental factors and student preparedness influencing CL outcomes (Keramati & Gillies 2022; Marzano et al., 2001).

Participants provided valuable suggestions for enhancing CL implementation, including early introduction of CL pedagogies, integration of CL activities into textbooks, and providing more opportunities for engagement, especially for medium and low-ability students. These suggestions align with recommendations from the literature. For instance, introducing CL early in students' educational journey has been shown to enhance their readiness and receptiveness to collaborative learning methods (Tadesse and Gillies, 2015). In addition, integrating CL activities into textbooks can facilitate seamless integration into regular classroom practices (Johnson et al., 2014). Furthermore, the emphasis on providing inclusive opportunities for engagement resonates with research highlighting the importance of catering to diverse student needs and promoting equitable participation in CL (Gillies, 2016; Webb, 2009).

CONCLUSION

The study confirms the efficacy of the jigsaw CL model in enhancing student learning outcomes in biology. Quantitative analyses reveal significant differences between the intervention and control groups, with CL yielding higher scores in PRS, AS, and OLG. Regression and correlation analyses further highlight the substantial contributions of PRS and AS to OLG. Qualitative insights identify implementation challenges such as student unfamiliarity, resource constraints, and teacher resistance, alongside recommendations including early introduction of CL, integration into textbooks, and inclusive engagement opportunities. Overall, CL emerges as a promising pedagogical approach for fostering collaborative learning experiences and enhancing student achievement in biology education, with potential for further optimization through addressing implementation barriers and integrating suggested improvements.

Study Limitations and Future Directions

This study presents several limitations that warrant consideration. First, the generalizability of findings may be constrained due to the focus on a specific educational context and grade level. While the results offer insights into CL's effectiveness in biology education, caution should be exercised when extrapolating these findings to broader populations or different educational settings. Second, reliance on self-reported measures for PRS, AS, and learning gains introduces potential biases, such as social desirability effects, which could impact the accuracy of reported outcomes. In addition, the observational component of the study is susceptible to observer bias, which may influence interpretations of classroom interactions and behaviors. Furthermore, while efforts were made to address various contextual factors affecting CL implementation, such as resource constraints and ideological misalignments, other unexplored variables might influence outcomes, necessitating further investigation. Finally, the study's exclusive focus on the jigsaw CL model may overlook potential variations in effectiveness across different CL approaches. Future research should diversify methodologies and address these limitations to provide a more comprehensive understanding of CL's impact on student outcomes across diverse contexts.

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AUTHORS' CONTRIBUTIONS

The primary author has designed this experimental study, conducted the analysis and interpretation of the data, and written the report. Three co-authors, serving as supervisors, have contributed significantly to the paper's writing by providing constructive comments and scientific reviews.

ETHICAL APPROVAL

This study was approved by the Ethics Committee of College of Natural and computational sciences, Hawassa University with the reference number CNCS-REC012/24. All participants provided informed consent before participation.

DATA AVAILABILITY

The data that support the findings of this study can be obtained from the corresponding author upon reasonable request.

CONFLICTS OF INTEREST

The author declares that there are no potential conflicts of interest.

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