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Assisting peer on distance learning as intervention to improve students' performance in mathematics: a cross-over study

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ABSTRACT

The global health pandemic necessitated a rapid shift to distance learning, prompting a need to explore effective instructional strategies. This study aimed to investigate the comparative effectiveness of assisting peer on distance learning (APDL) and conventional modular distance learning (CMDL) on grade 10 students' performance in solving problems on circles and coordinate geometry. A quasi-experiment using cross-over design was employed, involving a control group (n=20) using CMDL and an experimental group (n=20) using APDL. Data were collected through pre-tests and post-tests and were treated statistically using paired and unpaired t-tests and cross-over t-test. Results revealed a significant difference in post-test scores, with the APDL group outperforming the CMDL group, without carry-over effects. Both methods contributed to knowledge acquisition, but peer collaboration significantly enhanced problem-solving abilities. The study concludes that APDL is an effective strategy for enhancing mathematical performance in distance learning. Therefore, it is recommended that APDL be integrated into distance learning programs, teacher training should be provided, and further research should be conducted to optimize its implementation and explore its long-term effects.

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1. INTRODUCTION

The COVID-19 pandemic fundamentally reshaped the educational landscape, forcing schools to adopt distance learning models [1]–[3]. This "new normal" of education relies heavily on self-learning modules delivered remotely [4], [5]. While this approach offers flexibility, it raises concerns about its effectiveness in subjects like mathematics, which often require more interactive learning environments [6], [7]. Traditional lecture-based methods, effective in face-to-face classrooms, may not translate well to distance learning, potentially hindering student understanding and achievement.

Research suggests that numerous factors can hinder student performance in mathematics. The inherent difficulty of some mathematical concepts, coupled with a perceived lack of relevance in everyday life, can create a barrier to learning [8]–[12]. Additionally, traditional teaching styles often over-emphasize memorization of formulas, neglecting the development of deeper conceptual understanding [13]–[15].

Distance learning environments can worsen these existing challenges. Students struggling with self-directed learning may struggle to understand complex concepts taught solely through printed sources

[16]. The lack of immediate interaction with teachers further complicates the process, as students may hesitate to reach out for clarification on misunderstood topics.

While studies have explored the difficulties associated with distance learning in mathematics, there is a critical gap in research on effective interventions within this context [6], [17]–[19]. Existing research primarily focuses on identifying the challenges, leaving a void in practical solutions to address them [6], [17]–[19]. This study aims to bridge this gap by investigating the potential of assisting peer on distance learning (APDL) as a method to improve student performance in distance learning modality.

APDL as a learning intervention is hypothesized to leverage the power of peer collaboration within a distance learning framework. Pairing high-performing students with their peers who may be struggling may foster a supportive learning environment [20]–[23]. This approach offers several potential benefits. High-performing students can solidify their own understanding by explaining concepts to others [24], while struggling students receive personalized assistance from peers who can break down complex ideas in a more relatable way [25]–[26]. Additionally, the interactive nature of APDL may increase student engagement motivation [27], [28], learning skills and character formation compared to traditional self-directed learning [29].

The central focus of the current study is the investigation of the comparative effectiveness of APDL and conventional modular distance learning (CMDL) method in improving student performance in mathematics. While previous research used conventional pre-test and post-test design, this study utilized a more novel approach using a crossover design, allowing both groups to experience both methods. This approach helps isolate the specific effects of the APDL intervention by controlling for potential confounding variables such as baseline student differences or novelty effects associated with a new teaching approach. Analyzing the data collected using this design enabled the researchers to assess the treatment effect of APDL (the impact of the intervention compared to CMDL), the period effect (changes in performance over time regardless of the method), and the carryover effect (any lingering effects of one method on performance after switching to the other) [30].

The potential benefits of this study extend beyond the confines of this specific research question. If APDL proves successful, it can offer a practical and readily available strategy to enhance student understanding, engagement, and achievement. This approach could be readily implemented in various educational settings, promoting a more effective and supportive learning environment for students in a distance learning context.

2. METHOD

2.1. Research design

This study used a quasi-experimental method with a crossover pre-test and post-test design. This research design is appropriate in this study because it allows for a comparison of the APDL and CMDL methods while controlling for individual differences among students. The crossover design means students experience both teaching methods, serving as their own controls [30]. Additionally, the pre-test establishes a baseline understanding of mathematical concepts, helping to account for initial differences between students. This design offers a practical approach to investigate the effectiveness of different teaching methods in an educational setting, where random assignment is often impractical or unethical.

2.2. Participants

The study involved 40 grade 10 students from a single high school. To ensure a balanced comparison between the APDL and CMDL groups, researchers employed stratified random sampling. This method divided the students into strata based on their mathematics performance level. From each stratum, an equal number of students were randomly assigned to either the APDL or CMDL group. This approach helped to control for pre-existing differences in mathematical ability between the two groups, enhancing the study's internal validity. Matched groups based on mathematics performance were used to minimize the influence of other variables on the study's outcome, making it more likely that any observed differences in mathematical understanding can be attributed to the teaching method rather than pre-existing student abilities. Figure 1 shows the conceptual framework of the study using the cross-over research design.

2.3. Instrument

A researcher-made, 40-item pre-test and post-test assessed students' knowledge of circles and coordinate plane geometry. The instrument's content validity was ensured through expert review, and its reliability was established using test-retest procedures. It has an internal consistency coefficient of α=0.9022 which signifies that the instrument is valid and reliable.

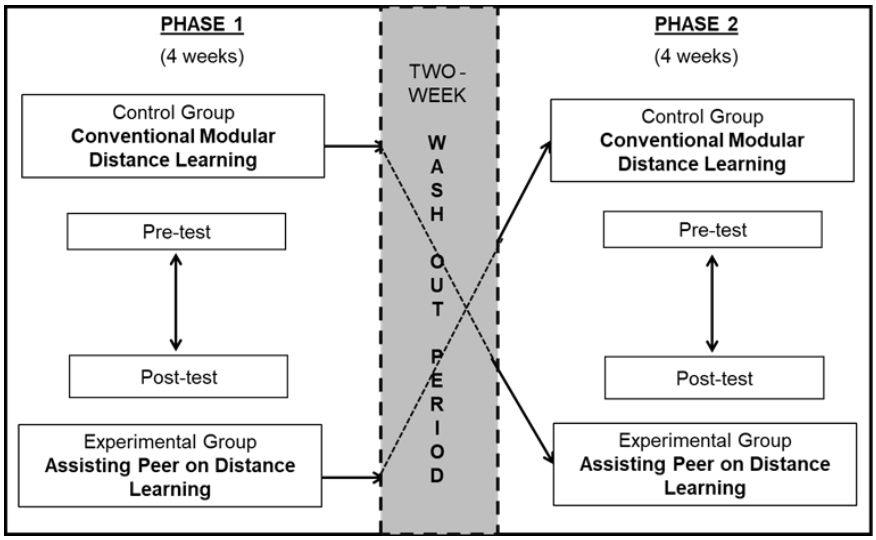

Figure 1. Cross-over design conceptual framework

2.4. Data gathering

The data collection process began with a pre-test administered to both groups to measure their existing knowledge. Following the pre-test, phase one commenced. In this phase, the control group received instruction through CMDL, while the experimental group participated in the APDL program. The high-performing students aided their peers in understanding the concepts. Once phase one concluded, both groups took a post-test specifically on circles. To minimize lingering effects from the first phase, a two-week washout period was implemented. Phase two then began with the groups switching methods. The control group now received APDL instruction, while the experimental group used the CMDL modules. Finally, after phase two, both groups completed a final post-test focusing on coordinate plane geometry. This multi-stage process allowed researchers to assess the effectiveness of the APDL method compared to CMDL method.

2.5. Data analysis

Descriptive statistics were employed to summarize the pre-test and post-test scores for both the APDL and CMDL groups. This involved statistical measures such as mean, standard deviation, and percentage to provide a clear overview of the data. Inferential statistics were utilized to draw conclusions about the effectiveness of the teaching methods. Paired t-tests were conducted to assess within-group changes in mathematical understanding between the pre-test and post-test for each group individually. This helped determine if there were significant improvements in scores within the APDL and CMDL groups. Crossover t-tests were used to compare the intervention effects between the two groups, allowing researchers to determine if one method led to significantly greater improvements in mathematical understanding than the other.

2.6. Ethical considerations

The research adhered to ethical principles by obtaining necessary permissions and informed consent from all relevant parties, including the school's division superintendent, school principal, and parents/guardians. Participants were assured of confidentiality, and their involvement was strictly voluntary. The study prioritized the well-being of the students by employing teaching methods that aimed to enhance learning outcomes. While the cross-over design involved switching teaching methods, precautions were taken to minimize potential negative impacts on student performance. Additionally, regular monitoring through home visitations ensured that students were not experiencing undue stress or difficulties.

3. RESULTS

Table 1 presents the results of the paired samples t-test comparing pre-test and post-test scores of the control group using the CMDL method in Phases 1 and 2. As shown in the Table 1, there is no significant difference between pre-test and post-test scores in Phase 1 ($t=1.940$, $p=0.434$) as well as in Phase 2 ($t=1.945$, $p=0.402$). These findings indicate that there was no significant improvement in the performance of control group participants in solving problems related to circles and coordinate geometry after implementing

the CMDL method. The students' ability to learn the concepts through this method appears to be consistent before and after instruction. This consistency may be attributed to the familiarity of students with the CMDL format due to its widespread use during the COVID-19 pandemic.

Table 1. T-test results on the difference between the pre-test and post-test performance of the participants in the control group using CMDL method

Phase	Variables	n	Mean	Mean difference	s	t	p	Result
Phase 1	Pre-test	20	5.80	1.65	0.46	1.940	0.434	Not significant
	Post-test	20	7.45					
Phase 2	Pre-test	20	8.25	0.10	0.44	1.945	0.402	Not significant
	Post-test	20	8.35					

Table 2 presents the results of the paired samples t-test comparing pre-test and post-test scores of the experimental group using the APDL method in Phases 1 and 2. Our findings show that there is a highly significant difference between pre-test and post-test scores in Phase 1 (t=10.871, p=0.000) as well as in Phase 2 (t=6.132, p=0.001). These findings indicate a significant improvement in the performance of experimental group participants in solving problems related to circles and coordinate geometry after implementing the APDL method. The students' ability to learn the concepts through peer assistance was notably enhanced.

Table 2. T-test results on the difference between the pre-test and post-test of the participants in the experimental group using APDL method

Phase	Variables	n	Mean	Mean difference	s	t	p	Result
Phase 1	Pre-test	20	5.15	6.75	0.53	10.871	0.000	Significant
	Post-test	20	11.90					
Phase 2	Pre-test	20	8.00	4.00	0.76	6.132	0.001	Significant
	Post-test	20	12.00					

Table 3 shows the results of the t-test analysis for treatment effect in the pre-test performance of control and experimental group. Our findings show that there is no significant difference in pre-test performance between the control and experimental groups (t=0.463, p=0.681). These findings suggest that the two groups exhibited comparable levels of prior knowledge regarding circles and coordinate geometry before the intervention.

Table 3. T-test analysis for treatment effect in the pre-test performance of control and experimental group

Compared groups	n	Mean	Mean difference	t	p	Result
CMDL	40	7.03	0.25	0.463	0.681	Not significant
APDL	40	6.78				

Table 4 presents the results of the t-test analysis for period effect in the pre-test performance of control and experimental group. It can be noted from the Table 4 that there is a significant difference in pre-test scores between Phase 1 and Phase 2 (t=5.282, p=0.002). These findings indicate that participants' performance on pre-tests improved over time, regardless of group assignment (control or experimental). This suggests that students may have gained additional knowledge, or skills related to circles and coordinate geometry between Phase 1 and Phase 2, potentially due to factors such as prior coursework or outside learning experiences.

Table 4. T-test analysis for period effect in the pre-test performance of control and experimental group

Compared groups	n	Mean	Mean difference	t	p	Result
Period 1	40	5.48	2.85	5.282	0.002	Significant
Period 2	40	8.33				

Table 5 presents the results of the t-test analysis for carryover effect in the pre-test performance of control and experimental group across the two sequences. As shown, there is no significant difference in pre-test scores between the control and experimental groups across the two sequences (t=0.621, p=0.527).

Our finding indicates that the order in which participants received the treatments (CMDL and APDL) did not significantly affect their pre-test performance. The sufficient washout period between the two phases likely prevented carryover effects from influencing the results.

Table 5. T-test analysis for carryover effect in the pre-test performance of control and experimental group

Compared groups	n	Mean	Mean difference	t	p	Result
Sequence 1	20	14.20	0.80	0.621	0.527	Not significant
Sequence 2	20	13.40				

There is a significant difference in post-test performance between the control and experimental groups as indicated in Table 6 showing the t-test analysis result for treatment effect in the post-test performance of control and experimental group (t=8.133, p=0.000). This finding suggests that the APDL method was significantly more effective than the CMDL method in improving students' understanding of circles and coordinate geometry. While both groups showed some improvement from pre-test to post-test, the experimental group demonstrated substantially higher levels of achievement.

Table 6. T-test analysis for treatment effect in the post-test performance of control and experimental group

Compared groups	n	Mean	Mean difference	t	p	Result
CMDL	40	7.90	4.05	8.133	0.000	Significant
APDL	40	11.95				

As presented in Table 7, there is a significant difference in post-test scores between Phase 1 and Phase 2 (t=4.647, p=0.003). This finding indicates that participants' performance on post-tests improved over time, regardless of group assignment (control or experimental). This suggests that the interventions implemented in both phases, the CMDL and APDL methods, contributed to the overall improvement in students' understanding of circles and coordinate geometry.

Table 7. T-test analysis for period effect in the post-test performance of control and experimental group

Compared groups	n	Mean	Mean difference	t	p	Result
Period 1	40	8.78	2.30	4.647	0.003	Significant
Period 2	40	11.08				

Table 8 presents the results of the t-test analysis for carryover effect in the post-test performance of control and experimental group across the two sequences. As the results indicated, there is no significant difference in post-test scores between the control and experimental groups across the two sequences (t=0.169, p=0.821). This finding suggests that the order in which participants received the treatments (CMDL and APDL) did not significantly affect their post-test performance. The sufficient washout period between the two phases likely prevented carryover effects from influencing the results.

Table 8. T-test analysis for carryover effect in the post-test performance of control and experimental group

Compared groups	n	Mean	Mean difference	t	p	Result
Sequence 1	20	19.75	0.20	0.169	0.821	Not significant
Sequence 2	20	19.95				

4. DISCUSSION

The present study sought to compare the effectiveness of APDL and CMDL methods on grade 10 students' performance in solving problems on circles and coordinate geometry. The results of this study APDL method significantly improves students' problem-solving abilities. This indicates that students who participated in the APDL group demonstrated a notably greater improvement in their problem-solving skills compared to those in the CMDL group. This suggests that the collaborative and interactive nature of the APDL approach was particularly effective in developing students' capacity to tackle mathematical challenges [31]–[33]. This is consistent with a growing body of research that reveals the potential of peer collaboration in attaining academic success [20]–[23], [31]–[37].

A key finding was the significant improvement in post-test scores for both groups across phases, suggesting that both methods contributed to knowledge acquisition. However, the more pronounced gains in the APDL group highlight the unique benefits of peer interaction [35]–[37]. The absence of significant carryover effects indicates that the order in which students experienced the two methods did not influence the outcomes, suggesting that both methods can be implemented independently [38]. The effectiveness of the APDL method can be attributed to several factors. Peer collaboration can create a supportive learning environment where students feel more comfortable asking questions and seeking clarification [20]–[23], [31]–[36]. The opportunity to explain concepts to peers can deepen students' understanding. Moreover, peer feedback can provide valuable insights and alternative perspectives, leading to enhanced problem-solving skills.

It is essential to note that while the APDL method demonstrated significant advantages, the CMDL method also contributed to learning gains. This suggests that both approaches have a role to play in distance learning environments [39]. However, the findings of this study indicate that incorporating peer interaction can significantly amplify the effectiveness of distance education.

The absence of significant period and carryover effects in this study is noteworthy. It indicates that the observed differences in post-test scores can be attributed primarily to the treatment effect, rather than extraneous factors related to time or sequence of intervention. This strengthens the causal inference that the APDL method was responsible for the enhanced performance of the experimental group compared to the CMDL method. Furthermore, lack of a period effect suggests that factors unrelated to the treatment, such as maturation or historical events, did not significantly influence the outcome measures. This strengthens the internal validity of the study. Similarly, the absence of a carryover effect indicates that the prior exposure to one treatment did not impact the performance of participants in the subsequent treatment. This suggests that the washout period implemented in the study design was adequate to mitigate any residual effects of the initial treatment. These findings have important implications for research design and analysis. The careful control of extraneous variables, as demonstrated in this study, is crucial for establishing causal relationships between independent and dependent variables. Addressing potential threats to internal validity can increase the researchers' confidence in the validity of their findings. On the other hand, the absence of carryover effects suggests that crossover designs, which involve exposing participants to multiple treatments, may be feasible in future studies investigating the comparative effectiveness of educational interventions. However, careful consideration should be given to the potential for carryover effects in other research contexts.

The results of this study have important implications for educational practice. Schools and teachers can consider integrating peer-assisted learning into their distance learning programs to improve student outcomes [40]. However, successful implementation requires careful planning and teacher support. Factors such as group composition, peer roles, and the use of technology should be carefully considered.

While the findings are promising, it is important to acknowledge the limitations of this study. The sample size was relatively small, and the study was conducted in a specific context, which may limit the generalizability of the results. Future research should investigate the effectiveness of APDL with larger and more diverse samples. Additionally, longitudinal studies are needed to examine the long-term impacts of peer-assisted learning on student achievement and motivation.

5. CONCLUSION

The study investigated the effectiveness of APDL compared to CMDL on grade 10 students' performance in solving problems on circles and coordinate geometry. Results indicated that the APDL method significantly outperformed CMDL in enhancing students' problem-solving abilities. This finding shows the potential of peer collaboration as powerful tool in improving mathematical learning outcomes as well as learning engagement within a distance learning context. While both methods contributed to knowledge acquisition, the APDL method demonstrated a more pronounced impact on student performance. The absence of significant carryover effects suggests that the order of treatment administration did not influence the results, indicating the standalone effectiveness of both methods. However, the study highlights the superior efficacy of peer-assisted learning in promoting deeper understanding and problem-solving skills.

To maximize the benefits of peer-assisted learning, educators should consider integrating APDL into their instructional strategies. Comprehensive teacher training is essential for effective implementation. Future research should investigate into the optimal structure of peer groups, the role of technology, and the long-term impacts of this approach. Comparative studies with other instructional methods and qualitative investigations into student experiences are also recommended to gain deeper insights into the mechanisms underlying the effectiveness of peer-assisted learning.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest related to this research and no financial interests or relationships with organizations that might have influenced the outcome of this research.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [PMC], upon reasonable request.

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