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Efficacy of the PAL teaching strategy on learners' performance in TEOF: A case of selected secondary schools of Kabwe district, Zambia

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Abstract
This study investigated the efficacy of the PAL (Peer-Assisted Learning) strategy on learners' academic performance on the Turning Effect of a Force (TEOF). The study used a quantitative approach and employed the Solomon Four Group Design and the quasi-experimental "Nonequivalent Control Group Design to address the issue involved. Simple random sampling was used to select 131 participants from four secondary schools. 65 participants formed two experimental groups while 66 participants formed two control groups. Data was collected using achievement tests and analysed using one way ANOVA. The results showed that the PAL teaching strategy enhanced learner performance in TEOF by about 30 scores ($M = 30$, $F(3, 106) = 115.068$, $p < 0.05$). In view of this, two recommendations were made, the first one being that in Kabwe district of Zambia, the PAL strategy should be seamlessly integrated into various learning activities across subjects and grade levels in secondary schools. The other one is that to optimize the effectiveness of the PAL strategy, structured training programs should be provided in Schools (during SPRINT) for both peer tutors and learners, encompassing effective tutoring techniques, communication skills, and collaborative learning strategies to enhance the skills and confidence of peer tutors, ultimately improving learner performance.

Keywords: Peer assisted learning (PAL), turning effect of a Force (TEOF), efficacy and learner performance

Introduction

Background to the study

Research indicates that secondary school learners often underperform in physics compared to other subject areas (Examinations Council of Zambia, 2013) [9]. This is common, particularly on challenging topics such as TEOF (Coletta *et al*., 2012; Erinosho, 2013) [4, 7] and yet knowledge of this concept has a lot of applications. For example it is very useful in opening doors, using wrenches, steering wheels in motor vehicles, bottle openers, screwdrivers etc (Serway & Jewett, 2018) [31]. Some scholars attribute the learners poor performance on TEOF to factors like inadequate teaching materials, lack of qualified teachers, traditional teaching methods, and learner misconceptions (Examination Council of Zambia, 2013; Gok & Silay 2008; Mattern & Schau, 2002; Kaya & Boyuk, 2011) [9, 14, 24, 22]. As a result, various teaching strategies, such as Peer Instruction (PI), Flipped classroom and Peer Assisted Learning (PAL) have been developed to enhance learning efficiency (Mazur & Watkins, 2010; Cahyadi, 2004; Henning *et al*., 2008; Gok, 2015; Kaya & Boyuk, 2011) [25, 1, 16, 13, 22]. Among the three strategies above, PAL emerges as a promising strategy supported by substantive evidence for raising academic achievements in many countries (Topping & Ehly, 2001; Henning *et al*., 2008; Calhoon & Fuchs, 2003; Cahyadi, 2004; Hughes, 2011; Leung, 2015; Glynn *et al*., 2006; Ginsburg-Block *et al*., 2006; Parkinson, 2009) [33, 16, 2, 1, 18, 23, 12, 11, 28]. However, very little is known about the impact of PAL on learner performance in TEOF in the Zambian context. Hence this study which addressed this problem in selected secondary schools in Kabwe district of Zambia.

The study, grounded in Vygotsky's social constructivism theory (1978), underscored the significance of social interactions and collaborative knowledge construction, particularly within the Zone of Proximal Development (ZPD) and through scaffolding, highlighting the impact of social contact and cultural factors on cognitive development (Vygotsky, 1978) [35]. Utilizing Topping and Ehly's PAL framework (2001) [33], it integrated five categories—Organization and engagement, Cognitive Conflict, Scaffolding and Error Management, Communication Skills, and Affective Component—to optimize declarative and procedural knowledge and their application, emphasizing the iterative and non-linear nature of cognitive development (Topping & Ehly, 2001) [33]. Fig 1 visually represents the interconnectedness of PAL components and supports the study's argument for an iterative, non-linear model of PAL that evolves with the growth of peer connections and learning progression to deeper levels. PAL involves cognitive conflict, scaffolding, and error management for knowledge building, and communication skills, while the affective component emphasizes motivation, positive self-image, responsibility, ownership, and acknowledging ignorance and misinformation. Aligning with Vygotsky's theory, PAL is seen as essential for consolidating fundamental abilities through effective and engaged practice, applicable as learning advances from surface to deep levels and from declarative to procedural and conditional knowledge (Vygotsky, 1978) [35]. Therefore, the study provided a comprehensive understanding of PAL within the context of Vygotsky's social constructivism theory and Topping and Ehly's PAL framework shown in the figure below.

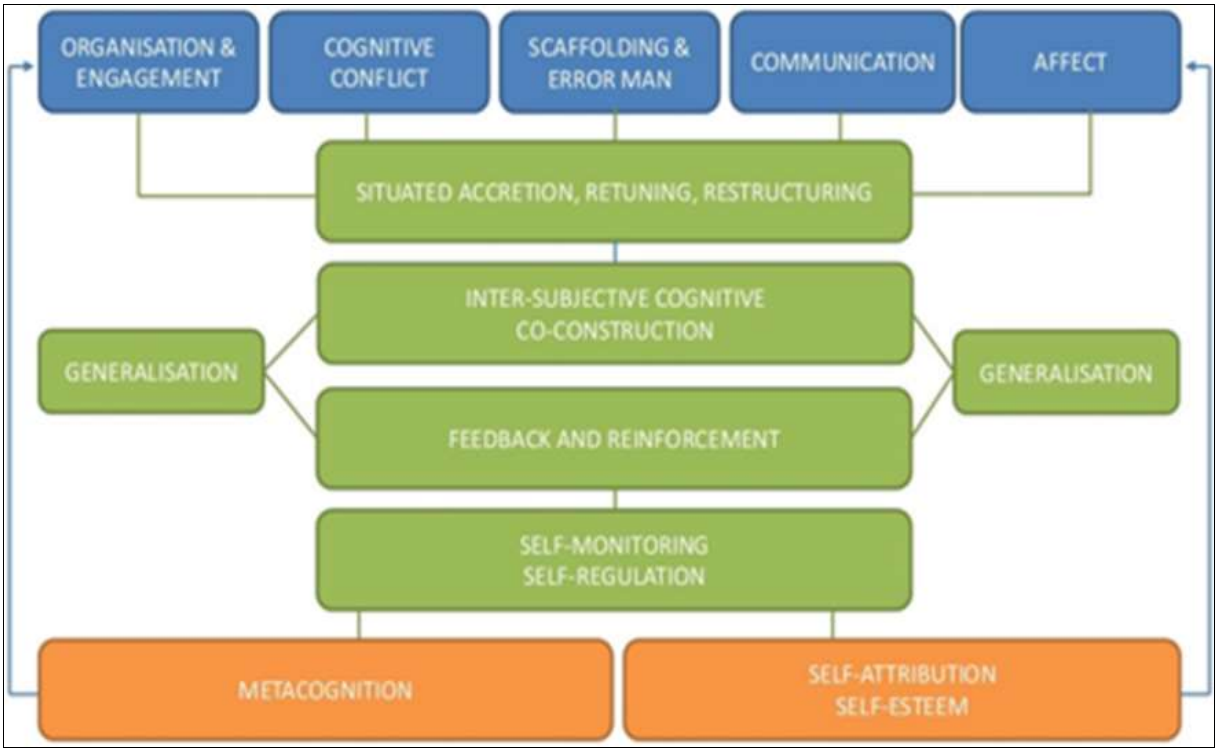

Fig 1: PAL framework by Topping and Ehly (2001) [33]

Operational definitions of key terms

A Peer in this study referred to a grade 10 learner. A Peer 'teacher' referred to a grade 10 learner teaching fellow learners. Academic performance referred to the scores obtained by learners in pre and post-tests on TEOF and Efficacy referred to the extent to which the treatment (PAL) enhanced performance of learners in TEOF.

Material and methods

This study utilized a quantitative approach. The quasi-experimental research design, specifically the "Nonequivalent Control Group Design" and the Solomon Four Group Design were employed to address the issue in question. The research was conducted in four selected secondary schools located in Kabwe district, Central Province of Zambia. The total number of participants involved in the study was 131 grade eleven pupils. Simple random sampling was used to select the schools in the district, after which four classes (1, 2, 3 and 4), were selected for data collection. Achievement tests, in the form of pre-tests and post-tests, were used to collect data. The data collection procedure involved selecting one class from each of the four schools. Classes 1 and 2 were administered a pre-test, while classes 3 and 4 were not subjected to a pre-test. Classes 1 and 3 were treated with the Peer-Assisted Learning (PAL) strategy and coded Experimental groups 1 and 3 respectively, where learners were given specific sections of the topic "turning effect of a force" according to the syllabus. They were then asked to conduct research on those sections, create notes, and develop tutorial questions with the assistance of the teacher. The students assumed the role of a teacher, while the subject teacher (the researcher) acted as the moderator. Classes 2 and 4, the control groups were coded Control 1 and 2. The collected quantitative data were analyzed using descriptive statistics, such as pre and post-test means and standard deviation, as well as inferential statistics, from ANOVA as generated by the Statistical Package for Social Sciences (SPSS).

Findings and discussion

The study involved 131 participants, with 52% females and 48% males. The results were as shown in tables 1 to 5 that follow.

Table 1: Learner performance on TEOF in pre and post-tests.

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
PreTest	Experimental 1	31	42.7419	10.18485	1.82925	39.0061	46.4778	25.00	60.00
	Control 1	32	41.9063	8.68948	1.53610	38.7734	45.0391	25.00	55.00
	Experimental 2	0	.	.	.	.	.	.	.
	Control 2	0	.	.	.	.	.	.	.
	Total	63	42.3175	9.38741	1.18270	39.9533	44.6816	25.00	60.00
PostTest	Experimental 1	31	84.0323	8.36853	1.50303	80.9627	87.1019	70.00	95.00
	Control 1	32	53.8125	7.10037	1.25518	51.2525	56.3725	40.00	65.00
	Experimental 2	34	82.0882	7.08976	1.21588	79.6145	84.5620	60.00	95.00
	Control 2	34	52.6471	8.27879	1.41980	49.7585	55.5357	40.00	80.00
	Total	131	68.0000	16.81483	1.46912	65.0935	70.9065	40.00	95.00

The pre-test results in Table 1 indicate that at the beginning of the study both the experimental and control groups, were at same level of performance. However, from the post-tests it is clear that after the treatment, the experimental groups that used PAL performed better than the control groups.
This indicated that PAL enhanced performance of the learners on TEOF by about 30 scores.
The statistics in table 2 below confirm that in the pretest, the groups did not differ in performance.

Table 2: Anova pre-test

	Sum of squares	df	Mean square	F	Sig.
Between groups	12.721	1	12.721	.112	.739
Within groups	5449.279	48	113.527		
Total	5462.000	49			

Table 2 tests for significance using $\alpha = .05$ and $p > .05$ showing that pre-test scores between and within Experimental 1 and Control 1 scores did not differ significantly.

The statistics in table 3 below confirm that in the post-test, the experimental and control groups differed significantly in performance.

Table 3: Anova-post test

	Sum of squares	df	Mean Square	F	Sig.
Between groups	24697.938	3	8232.646	115.068	.000
Within groups	7583.880	106	71.546		
Total	32281.818	109			

The results in table 3 show that the post-test scores differed significantly between the groups.
One-way ANOVA indicated a significant difference in mean scores across the four groups ($F(3,106) = 115.068$, $p < .05$). Post-hoc tests revealed significant differences between experimental group 1 and control groups 1 and 2, and between experimental group 2 and control groups 1 and 2 ($p < .01$). No significant difference was found between experimental group 1 and experimental group 2 (p-value =.845).
Multiple comparisons of the four groups was done and the statistics in table 4 below further confirm the above results.

Table 4: Multiple comparisons- post-test Tukey HSD

(I) Experimental and control groups	(J) Experimental and control groups	Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
Experimental 1	Control 1	30.21976*	1.94747	.000	25.1498	35.2898
	Experimental 2	1.94402	1.91908	.742	-3.0521	6.9401
	Control 2	31.38520*	1.91908	.000	26.3891	36.3813
Control 1	Experimental 1	-30.21976*	1.94747	.000	-35.2898	-25.1498
	Experimental 2	-28.27574*	1.90333	.000	-33.2308	-23.3207
	Control 2	1.16544	1.90333	.928	-3.7896	6.1205
Experimental 2	Experimental 1	-1.94402	1.91908	.742	-6.9401	3.0521
	Control 1	28.27574*	1.90333	.000	23.3207	33.2308
	Control 2	29.44118*	1.87427	.000	24.5617	34.3206
Control 2	Experimental 1	-31.38520*	1.91908	.000	-36.3813	-26.3891
	Control 1	-1.16544	1.90333	.928	-6.1205	3.7896
	Experimental 2	-29.44118*	1.87427	.000	-34.3206	-24.5617

*. The mean difference is significant at the 0.05 level.

Gender-based score variations were not statistically significant in all groups. The study aligns with Topping and Ehly (2001) [33], showing significant improvements in mathematical abilities with Peer-Assisted Learning (PAL). Roscoe and Chi's (2007) [30] meta-analysis supports PAL's positive impact across subjects. Johnson *et al*. (1993) [19] found PAL, including cooperative learning, significantly improved academic achievement. This contradicts Eryilmaz (2004), who suggests gender doesn't play a role in physics achievement.

From Tables 5, it can be noted that the groups that share the same column are not significantly different. As can be seen, Experimental 1 and Experimental 2 share the same column; hence, they are insignificant. Control 1 and Control 2 also share the same column; hence, they are insignificant. Groups that do not share the same column are significantly different like Control 1 is in column 1 while both experimental groups are in column 2; hence there is a significant difference between the groups.

Table 5: Homogeneous subsets-post-test Tukey HSD

Experimental and control groups	N	Subset for alpha = 0.05	
		1	2
Control 2	34	52.6471	
Control 1	32	53.8125	
Experimental 2	34		82.0882
Experimental 1	31		84.0323
Sig.		.929	.740

The graph in Figure 1 also confirms the results above. The Control groups' post-test means are more or less the same and this is the case with the post-test mean of the Experimental groups. The steepness of the slope shows that the treatment enhanced performance of learners on TEOF. In this case, the PAL strategy helped the learners to get higher test scores on TEOF.

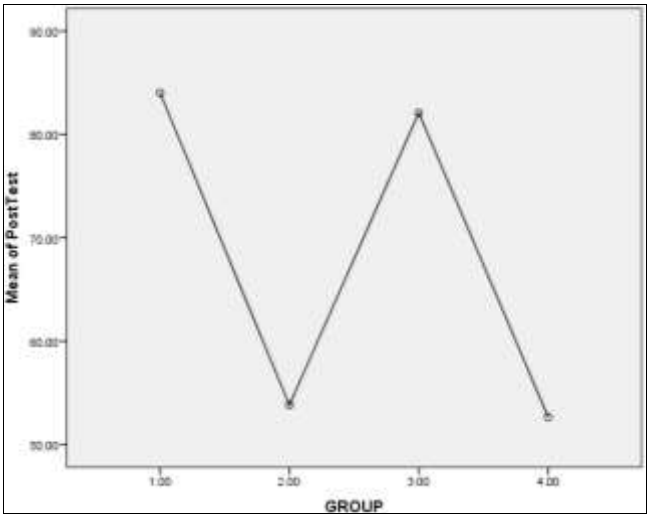

Fig 1: The graph of groups vs. Mean of post-test

Literature is consistent with the finding in this study. Topping and Stewart (1998) [34] demonstrated PAL's positive impact on reading achievement, while Abdullah *et al*. (2020) also found that PAL interventions positively impacted nursing students' academic performance. In the medical field, Roh (2021) [29] observed PAL's effectiveness in improving critical thinking. Falchikov and Goldfinch's (2000) [10] meta-analysis showed PAL's positive effects on higher-education students' academic achievement. Okilwa and Shelby (2010) [27] found peer tutoring positively affected students with disabilities, supported by Hager (2018) [15], indicating improved attitudes toward mathematics through PAL among first-year undergraduate students. Mueanploy's (2016) study, with 72 students, found PAL significantly improved conceptual understanding of magnetic fields and problem-solving ability. Dancer *et al*. (2015) [6] also reported PAL improved academic performance in a business course.

However, sometimes the above may not be the case due to other factors such as: subject area, student characteristics and the way PAL is implemented.

Conclusions and recommendations

When the PAL strategy is used appropriately, it enhances performance of learners on TEOF in secondary schools of Kabwe district, Zambia.

In view of the above conclusion, two recommendations are made:

- In Kabwe district of Zambia, the PAL strategy should be seamlessly integrated into various learning activities across subjects and grade levels (in secondary schools), including classroom discussions, group projects, problem-solving tasks, and study sessions. This approach ensures that learners benefit from diverse perspectives, engage actively, and develop a profound understanding of the content
- To optimize the effectiveness of the Peer-Assisted Learning (PAL) strategy, the structured training programs should be provided in Kabwe district secondary schools (during SPRINT) for both peer tutors and learners, encompassing effective tutoring techniques, communication skills, and collaborative learning strategies to enhance the skills and confidence of peer tutors, ultimately improving learner performance.

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