The Effect of Peer Instruction on Secondary School Learners' Attitudes towards Physics

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Abstract

In purposively selected nine-year basic education schools (two rural and two urban), we compared the effect of one interactive engagement method known as peer instruction on students' attitudes towards physics. To achieve intended objectives, we used a quasi-experimental design. The intervention lasted six weeks and involved 136 students from selected schools. Data were collected using our designed, valid, and reliable attitudinal test. We used descriptive and inferential statistics to analyze the data, employing repeated measures analysis of variance (ANOVA). Our findings revealed that teaching with peer instruction positively influenced students' attitudes toward the importance of physics learning and their understanding of different daily life circumstances. In addition, peer instruction was discovered to positively affect how students consider their experiences and apply them to the material being studied while understanding physics. A positive influence over students' attitudes toward their beliefs that the utmost critical aspect of physics problem-solving is determining an appropriate formula to apply was observed. The effect of peer instruction on the attitudes of students from rural schools was observed to be greater than the effect on those from urban schools.

Keywords: peer instruction; problem-solving in physics; students' attitudes towards physics

Introduction

Physics curriculum designers and educators should consider students' attitudes because a successful physics program necessitates changing their attitudes toward physics. According to research, actions, cognitive capacities, and academic achievement are linked. Students' attitudes and conceptual learning gains positively correlate (Adams et al., 2006; Civelek et al., 2014; Kurniawan et al., 2019). It was reported that students' opinions are influenced by instructional methodologies and their classroom experience (Adam et al., 2006; Elby, 1999; Perkins et al., 2006). It was reported that wrong views toward the discipline may harm students' academic achievement. Moreover, low enrollment in high school and university physics programs has been reported to be linked with students' negative attitudes toward physics (Antwi et al., 2011; Bates et al., 2011; Erdemir, 2009).

In Rwanda, the teacher-centered approaches are often used in physics learning and teaching, and students' active learning is ignored (Uwizeyimana et al., 2018). Other studies stated that teacher-centered approaches like lecturing, chalkboard writing

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(Ndihokubwayo et al., 2020), and group work (Byusa et al., 2020) are still used in Rwanda. Most teachers stressed presentation over coaching students on what to accomplish while doing group work, and students spent significant amounts of time listening to the teacher and writing notes (Byusa et al., 2020). As traditional methods do not provide adequate opportunity to students for argumentation and critical thinking, many learners learn a little physics in those classes using these methods (Crouch & Mazur, 2001; Muise, 2015). Courses employing a variety of collaborative pedagogical approaches are more effective (Brewe et al., 2013; Lindsey et al., 2012; Otero & Gray, 2008; Zhang et al., 2017). Peer instruction (PI) among them was claimed to cause a significantly more positive attitude among students. PI in fundamental physics classrooms increased students' ideas and attitudes toward physics and their learning (Zhang et al., 2017).

In Rwanda, a low number of students choosing to study physics-related options at the upper-secondary school and university was reported (Mushinzimana & Sinaruguliye, 2016). Improving students' attitudes toward physics may result in an increase in the number of students opting to study physics at secondary school and university levels. Therefore, there is an imperative need for the investigation of ways of improving attitudes towards physics. The authors studied whether the PI approach (Wood, 2016) can be utilized to improve attitudes of students toward physics among Nine-Year Basic Education (9YBE) in Rwanda.

Literature Review

A study conducted in Indonesia reported that about half of the students showed negative attitudes towards physics learning, which had a correlation with conceptual understanding of physics, as clearly shown by the low level of understanding of the participants (Tanjung & Mufit, 2023). A recent study on Malaysian physics students showed a high, positive, and very significant correlation among epistemological beliefs, learning attitudes, and physics learning (Ibrahim et al., 2022). Primary school teachers' attitudes towards experimentation were found to be significant in teaching physics, particularly in dimensions of its usefulness, motivation to perform experiments, and confidence (Vlachos, Stylos & Kotsis, 2024). For science curricula development, in addition to knowledge, skills, and competencies, attitudes gained by prospective students are highly rated by science tutors in Rwanda (Kanamugire, Yadav, & Mbonyiryivuze, 2019).

The findings of a study on preservice primary teachers demonstrated that integration of gamification can show significant improvement in perception and motivation of students as indicated by their reporting of increased interest and enjoyment in physics and chemistry (Jiménez-Valverde, et al., 2024). The results of a study on physics students following two cooperative learning models for two different groups showed an increase in positive attitudes towards physics, particularly enjoyment in physics learning, and increasing efforts and time used for learning (Maison et al., 2021).

The teaching method of PI is particularly advantageous for students in developing interactive abilities during lectures and paying attention to the important principles and concepts (Lasry et al., 2008) and for improving problem-solving skills, confidence, and attitudes towards learning (Mbonyiryivuze et al., 2018). In PI, a lecture is made up of multiple mini-lectures that cover key principles and concepts in the topic. Each mini-lecture starts with a quick overview of a major topic, followed by a multiple-choice concept question. Students are given a brief amount of time to think about it and answer independently before engaging in a group discussion. Students are allowed to amend their answers at the end of this conversation (Al-Hebaishi, 2017; Gok, 2012; Lasry et al., 2008; Wood, 2016). Students must analyze, synthesize, evaluate, and present material to support a claim or resolve a problem in PI. As a result, the answers to these questions offer instructors immediate feedback on their students' conceptual knowledge, helping them to identify problematic topics that require immediate attention in a lecture (Al-Hebaishi, 2017). PI promotes student learning in general, as well as self-efficacy and academic motivation, and positive attitudes about learning (Al-Hebaishi, 2017; Gok, 2012).

Research has shown that courses that include PI promote higher student achievement compared to those that use a typical lecture-based approach (Schell & Butler, 2018). PI has been widely praised as a simple tool for encouraging active learning in secondary and tertiary classrooms worldwide. PI has been found to have a variety of positive learning outcomes, such as higher student engagement, increased retention in scientific majors, and improved conceptual comprehension (Schell & Butler, 2018). During PI, students are given time to construct responses before discussing them. Students are provided an opportunity to support and reflect on their choices during this instructional strategy. PI provides a method for both students and teachers to examine students' understanding of the concept (Mazur, 1997). Moreover, this teaching method has been proven to improve students' metacognition. It may benefit from explanation generation, which may be amplified by social influence among peers. While providing explanations, the explainer may be judged by peers as better. Students' metacognitive processes, such as spotting errors and judging the coherence of replies, improve as a result of the discussion (Tullis & Goldstone, 2020).

Students’ attitudes toward a fast-changing technology world will emotionally and materially impact their coping ability. As a result, research into attitudes about physics, and advice on how to improve their attitudes and enrolment and performance in the subject is critical (Mbonyiryivuze, Yadav & Amadalo, 2021). Although numerous studies on students’ attitudes toward physics and various approaches to improve their views have been undertaken in advanced countries, this study focuses on the effect of PI on students’ attitudes towards physics in Rwanda. According to the findings from the first phase of our project on students’ attitudes towards physics, more than a quarter of students in Rwanda’s 9YBE believed that it was tedious to study physics. About 39% believe that physics has no use in daily life. A bulk of respondents had a negative attitude about the effort required to learn physics. The respondents' overall rate of physics problem-solving ability was lower. The differences in answers between rural and urban schools were statistically significant for problem-solving, concept connections, and concept understanding. Numerous students in rural schools need to practice physics equations before utilizing them for different problems (Mbonyiryivuze et al., 2021). Therefore, the results from a study analysing the impact of PI on attitudes towards physics for selected students in Rwanda's Eastern Province and Kigali city's 9YBE are reported in this article. It discusses the variation of the impact of PI on the attitudes of senior two (S2) students by school location.

Methodology

This section describes the adopted research paradigm and approach, research design, sample, sampling methods, and data collection procedures. It also includes data analysis as well as ethical considerations.

Research paradigm and approach

The researchers adopted the post-positivism paradigm (Henderson, 2011) as there was no readymade classification of research strategy to which the researchers could follow. This was due to a limited number of previous studies on the effect of PI on students' attitudes towards physics at lower-level secondary schools and limitation to control each variable, which could affect the results. This paradigm gives the researchers flexibility in choosing procedures, techniques, and methods of research, and allows them to consider different perspectives to address the objectives. As the main interest of this study was studying the effect of PI on students' attitudes towards physics in a particular context (9YBE), a quantitative research approach was chosen to address the research objectives of the study.

Research design

While investigating the effect of PI on students' attitudes towards physics, a quasi-experimental design with nonequivalent groups and pre/post-test setting was used. This research design was appropriate as it enabled comparisons between the performance of students taught using PI versus those taught by a conventional approach, which involved lecturing, chalk and talk, as well as group work. By the conventional approach, students and teachers continued with their daily routine and procedures for six weeks. In our study, the designed test, Students' Physics Attitude Test (SPAT), was used for both pretest and posttests. The design of SPAT was described and discussed by Mbonyiryivuze et al. (2021). The treatment was done without disrupting the existing class setting with the usual class teachers in order to manage students' response effect of satisfying the researchers. Table 1 summarizes the research design used.

The treatment in this case was to expose the experimental groups to PI. The treatment was done without disrupting the existing class setting with the usual class teachers in order to manage students' response effect of satisfying the researchers. For this study, SPAT was given to both student groups as pre-tests and post-tests.

Location of the study and population

This research was conducted in four 9YBE schools from Gasabo (2 schools) and Kayonza (2 schools), respectively, in Gasabo and Kayonza districts from Kigali city and Eastern province, which were chosen for comparing urban and rural 9YBE students' attitudes towards physics. The population of this study was 238 physics students in senior two. From this population, we purposively selected a sample of participants from which control and experimental groups were allocated.

Table 1: Study's research design

Group	Pre-test	Intervention	Post-test
Experimental	SPAT	Peer instruction	SPAT
Control	SPAT	Conventional instruction	SPAT

Sample Description and Sampling techniques

The data in this study were obtained from 136 senior two physics students in 9YBE schools from Gasabo and Kayonza districts, as indicated in Table 2. In fact, none of these students had studied with the PI teaching procedure before. The purposive sampling was applied to select four schools comprising 9YBE schools from Kayonza and Gasabo districts from Eastern province and Kigali city, respectively, that were used for intervention. These four schools were purposively selected from eight 9YBE schools that participated in the baseline study (Mbonyiryivuze et al., 2021) on the initial status of 9YBE school learners' attitudes towards physics, before the intervention.

Table 2: The study's sample

Location	Group	Pretest			Post-test		
All Sampled	Control		74			74	
	Experimental		62			62	
	Total		136			136	
		Male	**Female**	**Total**	**Male**	**Female**	**Total**
Urban Sampled	Control	17	24	41	17	24	41
	Experimental	18	19	37	18	19	37
Rural Sampled	Control	21	12	33	21	12	78
	Experimental	14	11	25	14	11	25

Data collection instruments

Data were collected using our designed, valid, and reliable SPAT survey (Mbonyiryivuze et al., 2021). The pre-test and post-test were administered at the beginning and at the end of the chapter on electricity and magnetism. The third term was selected because it is where electricity and magnetism, as the topic of focus for this study, are taught according to the existing Rwandan academic calendar. The questionnaire used has two main parts, which were demographic data and students' attitudes towards physics. Out of 22 items, 3, 5, 5, 3, and 6 items are, respectively, related to personal interest, the link between physics and the real world, effort of learning physics, problem-solving skills, physics concept connection, and understanding. During a pilot study, Cronbach's alpha was 0.723.

Intervention procedures

The teachers in the schools of the control groups used traditional lecture methods, while the teachers of the experimental groups used PI during their lesson delivery (Lasry et al., 2008). At the beginning of the course, the teachers of the experimental groups got training on the use of PI during instruction. Two lessons of these trained teachers, while they were implementing PI, were observed, and some minor suggestions for good PI implementation were provided. During the later visits to each experimental school, the execution of PI was found to be successful.

Data analysis

After entering the collected data into Microsoft Excel, the data were cleaned and exported into SPSS (IBM SPSS 23 statistics version) for analysis using both descriptive and inferential statistics. For seven items (8, 12, 15, 16, 18, 19, 20, 21, and 22) among 22 items, their scaling was reversed compared to the remaining items, as they were negative statements in the SPAT. This adjustment was done through all data analysis for urban and rural secondary schools.

To analyse the effect of PI on learners' attitudes towards physics and the difference in terms of school locations, inferential statistics with repeated measures analysis of variance (ANOVA) and descriptive analyses were used. The hypotheses associated with the research objectives are

H_{01}: There is no significant difference in attitudinal change towards physics for S2 students taught using peer instruction and the traditional teaching method.

H_{02}: There is no significant difference in attitudinal change towards physics for S2 students taught using peer instruction and traditional teaching methods in terms of school location.

The null hypothesis for both pre-test and post-test was that the mean score of each category, i.e., control and experimental groups, and students from urban and rural schools, was the same. For this study, the significance level was set at =0.05. Before conducting inferential statistics analysis, we first checked the assumptions of using parametric tests (sample of more than 30, continuous data, equality of means, and normal distribution).

The data from SPAT fulfilled three assumptions for normality as the data from both pre and posttest were scores, the samples were above 30 participants, and Levene's test of equality of variances proved its non-significance ($p>.05$). So, this led the researchers to use a parametric test for our analysis. Repeated measures analysis of variance (ANOVA) under a general linear model was used because we had two independent variables (urban and rural schools) and one dependent repeated variable (pre-and post-test). ANOVA was also used to compare the findings of the control and experimental groups for pretests and posttests. The statistically significant p-value was set at $p < 0.05$. One-way ANOVA was used to determine the difference in student responses to the SPAT based on the school location groups.

Ethical considerations

The permission to carry out this study was obtained from the relevant authorities. Authorizations to conduct the study in Gasabo and Kayonza districts were requested from the Director of Education in these respective districts, from which selected sample schools were chosen. All participants were provided information related to the study, its aim, methods, potential risks, and advantages before collecting any data. The participants signed the consent form and were given complete freedom to leave the study at any time. Respondent information was handled privately. Data were exclusively utilized for academic reasons and were securely stored.

Results and Discussion

We report the findings of the effect of PI on learners' attitudes towards physics in terms of groups (control and experimental) for school location and gender for both pretest and posttest. Table 3 shows normality testing results for SPAT. The finding from ANOVA was appropriate to find out if there is a difference between schools from urban and rural areas. The results found from both repeated measures ANOVA and descriptive analysis are going to be reported in this section, starting with those obtained by using ANOVA.

Table 3: Tests of normality for SPAT data

		Kolmogorov-Smirnov[a]			Shapiro-Wilk			Levene's test for equality of Variances	
Test	Location	Statistic	df	Sig.	Statistic	df	Sig.	F	Sig.
Pre-test	Urban	.074	78	.200	.985	78	.504	0.007	0.933
	Rural	.082	58	.200	.988	58	.813		

Table 4: Multivariate Tests for the Overall Sample for SPAT

Effect	**Test**	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**	**Partial Eta Squared**
Test * District	Wilks' Lambda	0.998	.210	1	134	0.647	0.002
Test * Group	Wilks' Lambda	0.999	.079	1	134	0.779	0.001

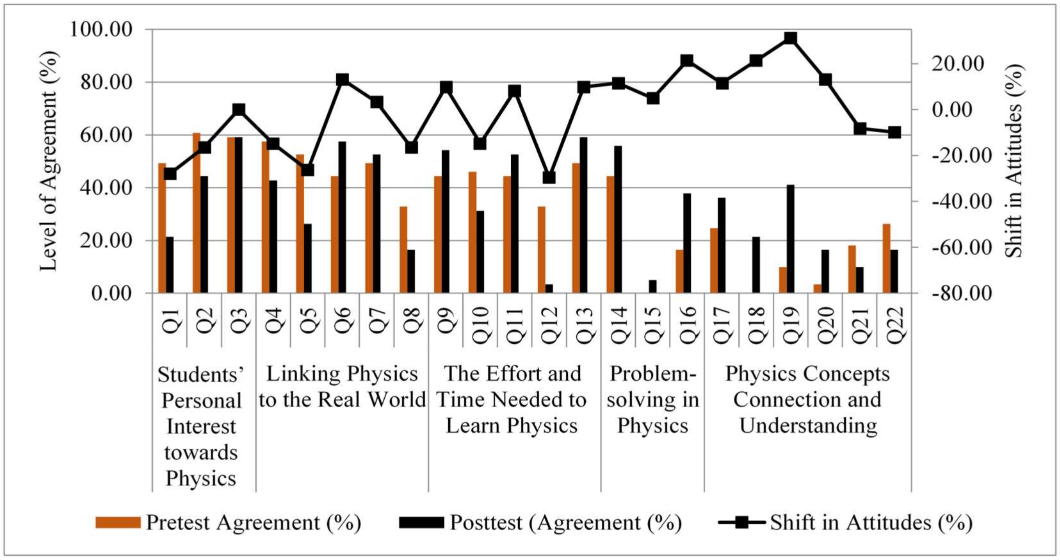
Table 4 shows that for school groups (F=.079, df=1, p>.05, $\eta^2 = .001$) and school location (F=.210, df=1, p>.05, $\eta^2 = .002$), there was no statistically significant difference. These results were supported by those obtained from descriptive statistics analysis, as indicated in the following section.

Descriptive analysis revealed that there were slight positive shifts in mean scores for the overall participating students' attitudes towards physics for both urban and rural schools. The results of changes in the learners' attitude towards physics in the experiment in urban schools for control and experimental groups are presented in Figure 1.

For the urban control group, the shifts in agreement levels are shown in Figure 1. The findings for the urban control group reveal a very slight difference in the impact of the traditional teaching method on learners' attitudes towards physics.

Despite the lack of overall positive change in students' personal interest in physics, a significant shift was observed in their attitudes towards physics to real-world applications. Specifically, the responses to item 6 indicated a notable 13.15% increase in students' agreement that physics laws relate to their real-world experiences. This suggests that while traditional teaching methods may struggle to enhance students' intrinsic interest in physics, they can still effectively convey the practical importance and applicability of physics concepts. This outcome highlights the potential of contextual and real-world examples within traditional pedagogy to bridge the gap between theoretical knowledge and everyday experiences, even if they do not necessarily make the subject more personally engaging for students.

Figure 1: Descriptive analysis for SPAT data for control group [N: 41]

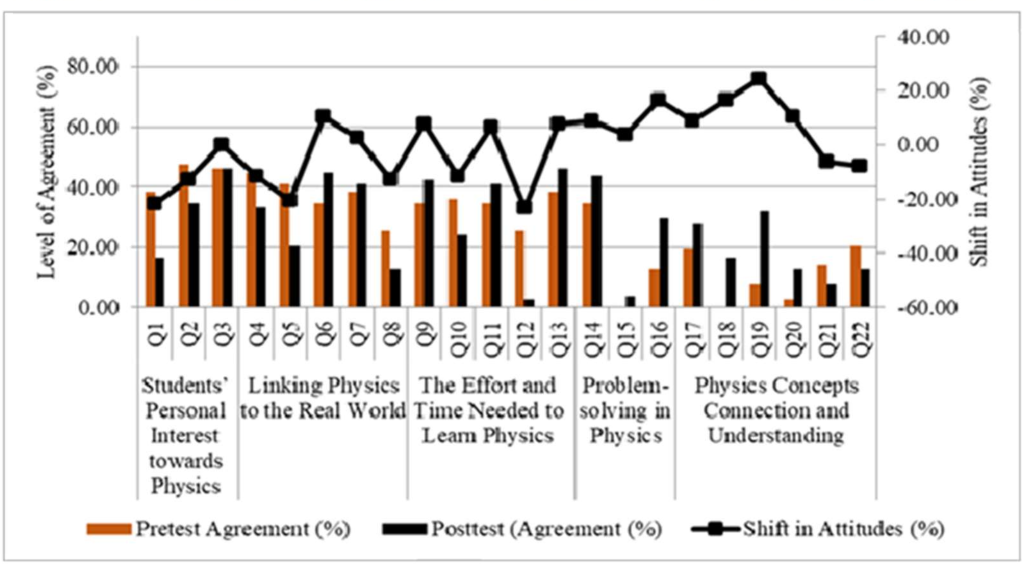


Consequently, educators might consider integrating more real-world applications and examples into traditional teaching to enhance students' appreciation of the subject's relevance, even if these methods alone are insufficient to boost overall interest in physics.

Let us see how the situation for the experimental group is. The respective shifts in participants' attitudes are mentioned in Figure 2.

While investigating the impact of PI on students' personal interest in physics for the urban experimental group, it was found that

Figure 2: Descriptive analysis for SPAT data for experimental group [N: 37]

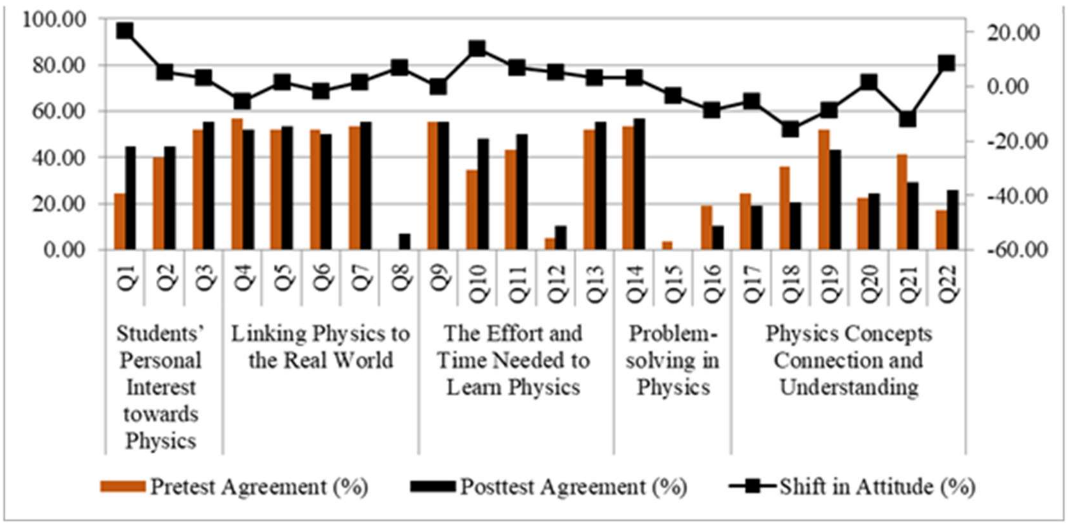


the participants' attitudes were not impacted positively regarding their personal interest in physics. However, for the dimension of participants' attitues towards the physics' link to the real-world applications, it was found that participants believe that physics laws are related to their real-world experiences (shift of 10.26%).

However, when asked what to do if they cannot solve a problem within 10 minutes, most participants said that they would give up and leave it, as indicated by their negative shift of -23.08% after being taught with PI. This is worrisome as it shows that most urban participants don't put much effort and afford time while solving physics problems. Many students use memorization to pass exams. Hence, they can't retain physics concepts in their memory for a long period. Because of memorization of physics formulas and lack of retention and organization of physics concepts and principles, students cannot apply their physics knowledge in everyday life situations. Previous studies found that learners' basic skills in cognitive and affective domains are affected by their conceptual knowledge. Thus, the learners' competence and skills can be improved by the concept-based learning (Amin et al., 2014; Khan & Saeed, 2021).

The effect of PI on learners' attitude towards physics in rural schools for control and experimental groups

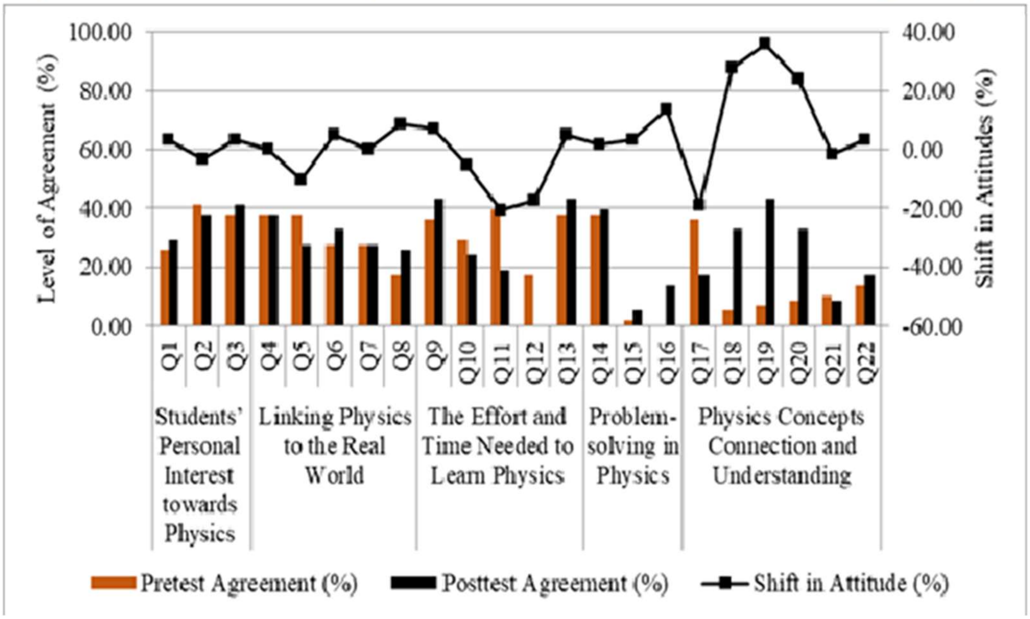
Figure 3: Descriptive analysis for SPAT data for control group [N: 33]



For the control group in rural schools, the shift in attitudes was low compared to the experimental group. The shifts in agreement levels for all items are mentioned in Figure 3.

For the impact of traditional teaching methods on students' personal interest in physics for the rural control group, it was found that the participants' attitudes were impacted positively. The highest shift of 20.69% was found for the item testing participants' enjoyment while studying physics. The same findings were revealed for the other remaining four dimensions. However, for the dimension of participants' attitudes towards the effort and time required for physics learning, it was found that there was a positive shift of 13.79 in this dimension of participants' attitudes, indicating that learners developed a more favorable perception of the efforts required to engage with physics after the intervention. Participants showed improved attitudes toward the effort and time required in physics learning, viewing it as less demanding and more manageable after the intervention. The shifts in agreement levels for the experimental group are mentioned in Figure 4.

Figure 4: Descriptive analysis for SPAT data for experimental group [N: 25]



Students' attitudes toward the importance of learning physics in helping them understand various situations in their daily lives were significantly influenced by PI as well as the students' belief in applying their personal experiences while studying physics. The use of PI also had a positive impact on students' beliefs that knowing which formula to use is the most important part of solving a physics problem.

These findings are in agreement with the literature reported that PI improves learners' basic concepts and problem-solving skills (Crouch & Mazur, 2001; Gok, 2012). Our findings are also in agreement with the recent studies on the use of cooperative learning models for two different groups, showing an increase in positive attitudes towards physics, particularly in the dimensions of enjoyment in physics learning, and efforts and time used for learning (Maison et al., 2021).

For the impact of PI on students' attitudes towards physics in terms of school location, we found that for schools located in rural areas, the increase for the experimental group was greater compared with the control group in terms of shift in attitudes. For the experimental group, the shift in mean score was from mean score M=3.42 (Pretest) to M=3.50 (Posttest), while for the control group, it was from mean score M=3.55 (Pretest) to M=3.57 (Posttest) in the rural area. For schools located in urban areas, the increase in the level of agreement was observed for both control and experimental groups. However, the increase for the experimental group was almost the same as for the control group in the change in attitudes in urban areas.

Conclusions

For the experimental groups, PI significantly affected students' attitudes toward the importance of physics learning in understanding various circumstances in their daily lives. Furthermore, it was discovered that PI has a positive effect on students' perception of their personal experiences and applying it to the studied material while learning physics. PI also influenced participants' attitudes towards physics problem-solving in a positive way. For schools located in rural area, the increase in attitudes for the experimental group, who were taught using PI, was greater compared with the control group, who were taught traditionally, while for schools located in urban areas, the increase for the experimental group was almost the same as that for the control group.

The main limitation of the study is the small sample size in 9YBE. Future research can extend the sample size by including several schools in a detailed study about learners' attitudes towards physics and its effect on their academic performance and conceptual understanding.

Disclosure statement/ Conflicts of Interest

The authors declared no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in this study.

Data Availability Statement

The data presented in this study are available on request from the author since this research was conducted on students, for which their teachers gave consent.

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