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Improving students' performance and conceptual understanding of heat transfer using demonstration method

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ABSTRACT

One of the physics topics difficult to understand among students at senior high schools (SHSs) is heat transfer. Various reasons have been advanced in an attempt to rationalize this difficulty. This study through an action research design was conducted to improve students' performance and conceptual understanding of heat transfer at Oti Boateng Senior High School, Koforidua. The instruments used for the study were questionnaires, pre- and post-test. The study identified rote learning, inadequate understanding of concepts among others as the cause of difficulty in problem solving among students. The study revealed that although there are different methods of teaching, the efficacy of the demonstration method cannot be downplayed considering its role in improving students' academic performance. The study concluded that for effective teaching and learning of heat transfer at SHS, it is important for teachers to employ the demonstration method in their teaching.

Keywords: heat transfer, demonstrational method, understanding, physics

INTRODUCTION

One of the concepts in physics difficult to be understood among students is heat transfer. Various reasons have been advanced in attempt to rationalize the underachievement among students (Ikpe, 2014). Heat transfer is the process of thermal energy transfer due to temperature difference in a medium or media (Chauhan et al., 2023; Cheng et al., 2023; Kolsi et al., 2023; Lin et al., 2023). Whenever temperature difference exists in a medium or between media, heat transfer is manifested (Pagliarini et al., 2023; Li et al., 2023). The various methods of heat transfer are conduction, radiation and convention (Rashid et al., 2022; Vijay et al., 2022). Teaching of heat transfer is associated with some misconceptions. These misconceptions are known for creating conceptual difficulties among students (Depaepe et al., 2015). Brown et al. (2016) found that both students and teachers of physics were unable to accurately assess their understanding of heat transfer and temperature. Their research also revealed that there was no significant relationship between perceived understanding and actual conceptual understanding of heat transfer. Conceptual understanding requires clarification of misconceptions and offers the potential to engaging students in the teaching-learning process (Al-Sultan et al., 2021; Brown et al., 2016; Stovner et al., 2022). Therefore, the learner requires a deliberate effort to relate new knowledge to relevant concepts that they already possess (Hoffman et al., 2015).

One of the ways of minimizing student's misconception is implementing good teaching strategy through innovation to improve students' understanding. Michailidi and Stavrou (2021) aver that introducing an innovation should not only be limited to providing teachers with theoretical knowledge, or with a detailed rationale of the innovation. It must be accompanied with ongoing support during the attempted implementation. The ability of students to understand and solve problems related to heat transfer is very useful for their everyday life. It is therefore important for physics teachers to give much credence to the professional development and understanding of their students on heat transfer (Mena et al., 2017; Nandiyanto et al., 2020). Teachers are considered to play a leading role in influencing instructional quality and students' learning success (Meschede et al., 2017). Another problem associated to be creating conceptual difficulties among students is their mindset (Kertiyani et al., 2022). Students need to shift their minds and also take responsibility of what they study through critical thinking (Hoffman et al., 2015; Hokor, 2022).

To develop an enhanced understanding of heat transfer, research of some teaching methods provide a foundation upon which an experimental design could be prepared (LeBorgne et al., 2016). There are different types of instructional methods that are used by educators, based on the standards of education and the need requirements of students (Huerta et al., 2022; Parr et al., 2021; Sanders-Smith et al., 2016; Voskoglou, 2019). Todd et al. (2017) identified four instructional methods as active participation, case-based activities, a combination of individual and group approaches, and a small number of instructional methods.

The use of demonstrational method has been proved as an effective approach that makes learning more concrete and simpler (Barton et al., 2017; Haage et al., 2017; Liang et al., 2016). Demonstration is a teaching method used to communicate an idea with the aid of visuals such as flip charts, posters and PowerPoint. According to Ivanova and Nwosu (2013) teachers do not only demonstrate specific learning concepts within the classroom, but they also participate in the process. Demonstrations play an important role in developing deep insight and understanding of heat transfer concepts (Ahmad et al., 2021). Haage et al. (2017) aver that well prepared and properly presented demonstrations have the potential to enhance students' understanding of physics concepts. Similarly, Liang et al. (2016) in their comprehensive reviews, concluded that demonstrations have the potential to enhance learning, motivation, and attitudes. Demonstrations may enable learners acquire learning experience. This consequently increases their curiosity and enhance their reasoning abilities. In addition, it may have an impact on students' achievements. Moreover, there are occasions in which teachers' demonstrations are educationally more effective than students' own experimentations. A number of studies reported clear benefits when demonstrations are used for teaching heat transfer. In a study on college introductory physics courses, Buncick et al. (2014) found that demonstrations encourage generalization because they promote active participation on the part of students. An elevated level of student attention and involvement in tasks has also been reported for demonstrations carried out in high-school physics courses. For example, Schmid and Telaro (2018) have shown that demonstrations encourage student involvement, since they are less teacher oriented and give students an opportunity to produce questions and to become more active in the learning process.

However, most teachers favoured traditional teaching approach for teaching concepts, which reward learners' ability to reproduce facts without truly understanding the topic and predictably fails in the face of complex interactions (Isa et al., 2020; O'Shea, 2021; Schmid & Telaro, 2018). In recent years, science students in senior high schools (SHSs) have been scoring low marks in heat transfer due to teaching strategies such as lecture method adopted by the teachers. To improve students' comprehension on heat transfer, researchers have reported their ideas and strategies. Some researchers reported the use of direct observation (Schmid & Telaro, 2018), and software (Ardiana et al., 2018; Suryani & Ishafit, 2018) to explain heat transfer among SHS students. Nevertheless, these methods have not adequately helped in student's understanding. It is also a necessity to find good and practical strategies for teaching heat transfer. Unfortunately, until now, there appears to be limited research on how to apply effective teaching strategies in teaching heat transfer. Against this background, this study set out to use demonstrational method to improve students' performance and conceptual understanding of heat transfer at Oti Boateng Senior High School, Koforidua.

The present study was carried out to study the following objectives. Firstly, to determine the performance of students before the use of demonstration method in teaching heat transfer. Secondly, to ascertain the performance and conceptual understanding of students after the use of the demonstration method in teaching heat transfer and finally, to investigate students' perceptions about the use of demonstration method in teaching. To meet the objectives, the following research questions were posed:

1. What is the performance of students before using the demonstration method in teaching heat transfer?
2. What is the extent of students' performance and conceptual understanding of heat transfer after the use of demonstrational method?
3. What is the perception of students after applying the demonstrational method in teaching heat transfer?

METHOD

Research Design

The research design used to conduct this research was action research (Ronen, 2020). Action research unifies the process of developing theory and practice by finding immediate solution to local problems through the scientific method (Moch, 2016). Initially promoted by Kurt Lewin in the mid-1940s with the intention of applying research to practical issues, action research seeks to examine social situation, attempt change, and monitor results (Ronen, 2020). Action research design was chosen because it helped the researchers to achieve the purpose of the study, which was improving students' performance and conceptual understanding of heat transfer at Oti Boateng Senior High School. The three stages in action research design were considered. These are pre-intervention, intervention, and post-intervention stages. Pre-intervention stage considered administration of pre-test that identified students' knowledge on conceptual understanding of heat transfer. Intervention stage considered implementation of strategies on improving students' performance and conceptual understanding of heat transfer. Post-intervention stage also involved the administration of a post-intervention test to ascertain whether there were any significant improvements in students' average performance and conceptual understanding of heat transfer.

Population and Sample Size

Population is a complete set of elements (persons or objects) that possess some common characteristics defined by the sampling criteria established by the researcher (Troisi et al., 2022). The student population of Oti Boateng Senior High School is 3,000. The target population consisted of 30 students from form two science class.

Sample Technique

Sampling is the process of gathering information from a population (Christensen et al., 2019; Yu, 2019). Taherdoost (2016) defines sampling as taking a subset from chosen sampling frame or entire population. Purposive sampling technique aims at selecting cases, which will provide rich information in respect of the purpose of the study (Nassaji, 2015). Purposive sampling technique was used because it allowed the researchers to choose the participants who possessed the information that the researchers needed.

Research Instrument

Research instruments are tools used to collect information on the subject about the problem under study (McCaffrey et al., 2016). The main instruments used to collect data for the study were pre-tests, post-test, and questionnaires. This was to ensure that data were collected through variety of strategies to strengthen and vary the research findings. The pre-test was used during the pre-intervention stage to ascertain the existence and the degree of the problem while post-test was used in the post-intervention stage of the research to determine the effectiveness of the intervention strategy. Two separate questionnaires were designed for the study. One for the physics teachers and the other for the students to ascertain the use of demonstration method to improve students' performance and conceptual understanding of heat transfer.

Data Collection Procedure

Yin (2013) indicates that data analysis consists of examining, categorizing, tabulating, testing or otherwise recombining both quantitative and qualitative evidence to address the initial propositions of a study. For the purpose of this study, data collected from the pre-test, post-test, and questionnaires were analysed using bar chats. In presenting and analysing the data, simple statistical tools were used. That is, the scores on each test were converted into frequency tables and corresponding number of students who obtained scores within each category computed into percentages. A bar chart was used to represent the scores obtained in each test.

Pre-Intervention Stage

The researchers identified at Oti Boateng Senior High School between September and October 2022 that form two science students found it difficult in solving questions on heat transfer. It was also noted that quite a number of students became passive during delivery of lessons on heat transfer. Based on this, students were given pre-intervention questions (pre-test) to ascertain their interest and conceptual understanding of heat transfer. The pre- test consisted of twenty objective questions. The total score for the test was 20. The total score for each student was collated and tabulated. From the analysis of the data obtained after the pre-test, the researcher realised that most of the methods used to teach heat transfer in thermal physics were teacher-centred. These methods required from students to perform minimal activities. The analysis of the data revealed the urgent need to intervene with measure of remediation. The researchers also administered questionnaires to both physics' teachers and students on the use of demonstrational method to improve students' performance and conceptual understanding of heat transfer.

Intervention Stage

After the pre-test, an intervention approach was designed to improve students' conceptual understanding of heat transfer using the demonstration method. The intervention stage discussed the various measures instituted to enhance students' understanding of heat transfer. Four lessons were taught on heat transfer.

Post-Intervention Activities

After the interventions to help students learn heat transfer with less difficulty, students were given class exercises and later, post-intervention questions to ascertain whether they have improved on their performance on conceptual understanding of heat transfer.

Data Analysis Procedure

Data analysis is the process of inspecting, cleaning, transforming and modelling data with the goal of showing useful intonation, suggested conclusions and supporting decision making (Dozza et al., 2013). Raw data was obtained from the research that needed to be analysed. Responses of the students on each item of the pre- and post-intervention questions were examined and analysed descriptively. Frequency counts on the items were made after which they were converted to percentages for easy interpretation and analysis.

RESULTS

Results of Pre-Intervention Questionnaire (Students)

The pre-intervention questionnaire required from students to indicate their views on heat transfer. 30 students were given the questionnaires and their responses are provided in **Table 1**.

Item 1 required students to state whether they like studying physics or not. The responses showed that 11 students representing 36.7% like studying physics and the remaining 19 students representing 63.3% do not like studying physics. Those who do not like studying physics said they do not understand how it is taught and as a matter of fact they do not have any interest in it.

Item 2 required from the students to state whether they have been taught heat transfer or not. The results in **Table 1** indicated that 30 students (representing 100%) have been taught heat transfer.

Item 3 required from students to state if their teacher organizes activities to explain heat transfer concepts to them. The outcome from **Table 1** indicated that eight students (26.7%) said that the teacher organizes activities to explain heat transfer concepts to them. The remaining 22 students representing (73.3%) said the teacher does not use activities to explain heat transfer concepts to them. The outcome indicated that most of the heat transfer concepts was not taught through activities and due to that they did not understand heat transfer concepts well.

Table 1. Students responses to pre-intervention questionnaire

Items	NY	PY (%)	NN	PN (%)
1. Do you like studying physics?	11	36.7	19	63.3
2. Have you been taught heat transfer?	30	100.0	0	0.0
3. Does your teacher organize activities to explain heat transfer concepts to you?	8	26.7	22	73.3
4. Is heat transfer difficult to learn?	24	80.0	6	20.0
5. Does the teacher vary his or her teaching methods?	7	23.3	23	76.7
6. Do you demonstrate lessons on heat transfer in your day to day activities?	6	20.0	24	80.0
7. Do you participate in heat transfer lessons?	21	70.0	9	30.0
8. Does the teacher use praises and rewards during lessons?	17	56.7	13	43.3

Note. NY: Number of students who responded "yes"; PY: Percentage of students who responded "yes"; NN: Number of students who responded "no"; & PN: Percentage of students who responded "no"

Table 2. Methods used in teaching

Response	Number of teachers	Percentage of teachers (%)
Student centered	1	20.0
Teacher centered	3	60.0
Both	1	20.0
Total	**5**	**100.0**

Table 3. Attitude of students to learning of heat transfer

Response	Number of teachers	Percentage of teachers (%)
Positive	2	40.0
Negative	3	60.0
Total	**5**	**100.0**

Item 4 required students to state whether heat transfer is difficult to learn or not. The analysis from **Table 1** showed that 24 of the students representing 80% said heat transfer is difficult to learn and six students representing 20% of the class indicated that heat transfer is not difficult to learn. The outcome indicated that most of the students find it difficult in learning heat transfer. Their reason was that the teacher was not punctual in class and his method of teaching did not make them understand the concept well.

Item 5 required from students to state whether the teacher vary his or her teaching methods. The analysis from **Table 1** showed that seven of the students representing 23.3% said the teacher vary his or her teaching methods when teaching. 23 students representing 76.7% of the class indicated that the teacher does not vary his or her teaching method.

Item 6 required students to state whether they demonstrate lessons on heat transfer in their day-to-day activities. The analysis from **Table 1** showed that six of the students representing 20% demonstrate lessons on heat transfer in their day-to-day activities and 24 students representing 80% of the class indicated that they do not demonstrate lessons on heat transfer in their day-to-day activities.

Item 7 required students to state if they participate in heat transfer lessons or not. Results from **Table 1** indicates that 21 students representing 70% participates in heat transfer lessons and nine students representing 30% do not participate in heat transfer lessons with the reason being that they are not interested in it.

Item 8 required students to state whether the teacher uses praises and rewards during lessons. Results indicates that 17 students representing 56.7% said the teacher uses praises and rewards during lessons and 13 students representing 43.3% said the teacher does not use praises and rewards during lessons.

Results of Pre-Intervention Questionnaire (Teachers)

The pre-intervention questionnaire required the teachers to indicate their views on teaching and learning of heat transfer. Five teachers were given the questionnaires and their responses are provided. Item 1 required teachers to state which teaching methods they use in teaching. The results are indicated in **Table 2**.

The analysis from **Table 2** showed that one teacher representing 20% uses student centered method to teach, three teachers representing 60% uses teacher centered method to teach and one teacher representing 20% uses both the student centered and teacher centered method in teaching. The teachers who use teacher centered method said the syllabus was loaded and the academic calendar was too short. The calendar contained some public holidays and some activities like inter-house athletics, inter-school and college games. Another reason was that other teaching methods to them waste time and therefore they needed to cover a lot before the end of the term or academic year.

Item 2 required teachers to state the attitude of students towards learning. The results are indicated in **Table 3**.

The analysis from **Table 3** showed that two teachers representing 40% said attitude of students towards learning of heat transfer is positive and three teachers representing 60% said the attitude of students towards learning of heat transfer is negative. Some of the teachers said most students do not show interest in heat transfer.

Item 3 required teachers to state whether heat transfer is difficult to teach or not.

Table 4. Results of teachers' questionnaire

Items	NY	PY (%)	NN	PN (%)
3. Is heat transfer difficult to teach?	3	60.0	2	40.0
4. Do you organize practical lessons under heat transfer for your students?	3	60.0	2	40.0
5. Do students contributes effectively to your heat transfer lessons	2	40.0	3	60.0

Note. NY: Number of teachers who responded "yes"; PY: Percentage of teachers who responded "yes"; NN: Number of teachers who responded "no"; & PN: Percentage of teachers who responded "no"

Table 5. Pre-intervention test results

Range of scores (x)	Frequency (f)	Percentage (%)
0-5	16	53.3
6-10	10	33.4
11-15	3	10.0
16-20	1	3.3
Total	**30**	**100.0**

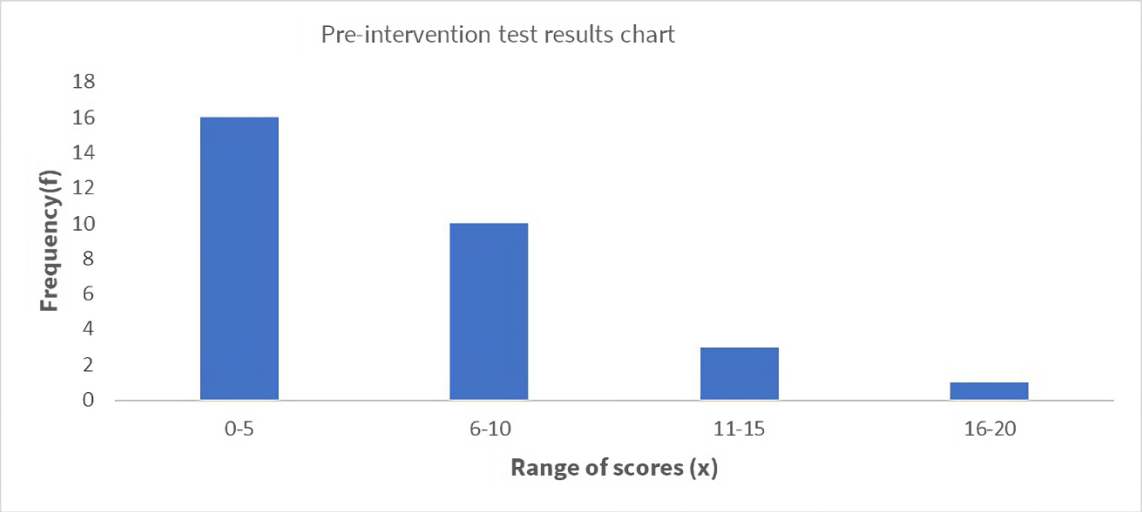

Figure 1. Bar chart of pre-intervention test results (Source: Authors' own elaboration)

The analysis from **Table 4** showed that three teachers representing 60% said it is difficult to teach heat transfer. Their reason was that there is inadequate equipment in the science laboratory to explain heat transfer concepts practically to students. On the other hand, two teachers representing 40% said heat transfer is not difficult to teach.

Item 4 required teachers to state whether they organize practical lessons under heat transfer for their students. The analysis from **Table 4** showed that three teachers representing 60% organizes practical lessons under heat transfer for their students and two teachers representing 40% do not organize practical lessons under heat transfer for their students.

Item 5 required teachers to state whether students contribute effectively to the heat transfer lessons. The analysis from **Table 4** showed that two teachers representing 40% said students contributes effectively to their heat transfer lessons and three teachers representing 60% said students do not contribute effectively in their heat transfer lessons.

Pre-Intervention Test Results

A pre-intervention test was administered to determine students' difficulties in studying heat transfer. **Table 5** summarizes the pre-intervention test data.

Figure 1 represents the pre-intervention test results. It shows the number of students and their range of scores.

Data from the pre-intervention test showed that majority of the students performed poorly in the test: 53.33% performed below average scoring between 0-5 marks. Also, 10 (33.34%) of the students scored between 6-10 marks indicating an average performance, three students representing 10% of the total distribution scored between 11-15 indicating above average performance and only on person scored between 16-20 marks. Generally, the results above indicate that students' performance was very poor. It can therefore be concluded from the findings that about 86% of the students (sample) performed poorly in the test taking five as the pass mark. The bar chart gives accurate picture of the seriousness of the problem.

Post Intervention Test Results

A post-intervention test was administered to determine the level of students' understanding of heat transfer. **Table 6** summarizes the post-intervention test data.

Figure 2 represents the post-intervention test results. It shows the number of students and their scores.

Table 6. Post-intervention test results

Range of scores (x)	Frequency (f)	Percentage (%)
0-5	0	0.0
6-10	3	10.0
11-15	8	26.7
16-20	19	63.3
Total	**30**	**100.0**

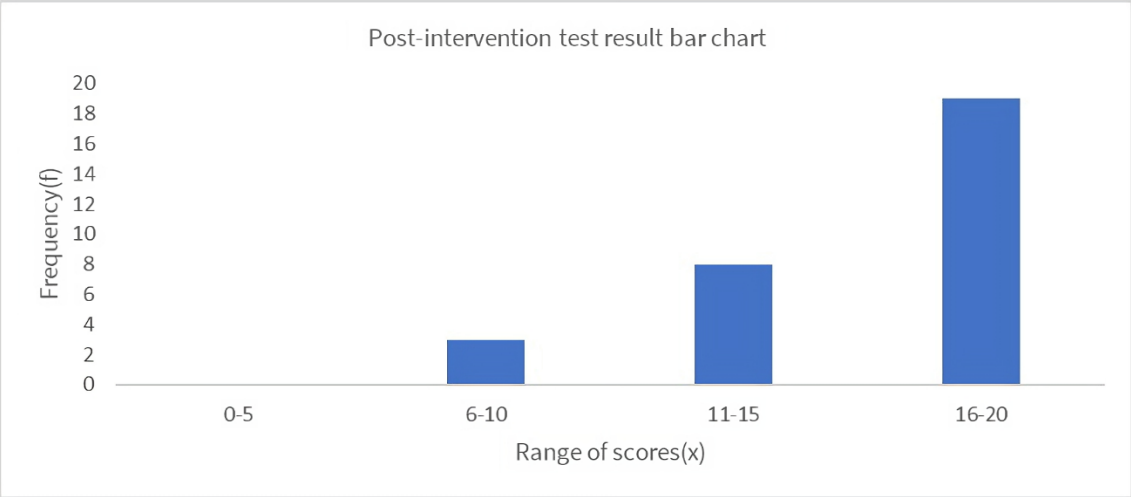

Figure 2. Bar chart of post-test results (Source: Authors' own elaboration)

Table 7. Comparison of pre and post intervention test results

Range of scores (x)	Pre-test		Post-test	
	Frequency (f)	Percentage (%)	Frequency (f)	Percentage (%)
0-5	16	53.3	0	0.0
6-10	10	33.4	3	10.0
11-15	3	10.0	8	26.7
16-20	1	3.3	19	63.3
Total	**30**	**100.0**	**30**	**100.0**

The post intervention test results showed that majority of the students scored above average (10 marks). With 10 as the pass mark, 27 students scored above it is representing a percentage of 90%, three students representing 10% scored 6-10, which is below average, and no student scored 0-5 marks. The post intervention test bar graph has shown the improvement in students' performance. The effectiveness of the intervention can be seen from the improvement in the performance of the students in the post test as compared to that of the pre-test.

Comparison of Pre-Test and Post Test Results

Table 7 compares the marks of the students for pre- and post-test expressed in percentages.

Figure 3 shows the comparison of the charts of results of pre- and post-test.

The data presented on the pre-intervention test has shown that most of the students (26) scored below average with a percentage of 86.67% and four students representing 13.33% scored above average. But post-test results gave 90% of the students scoring above average, and 10% scoring below average. It can thus be inferred from the data presented that the demonstration method has been effective and efficient in improving the performance and conceptual understanding of students on heat transfer.

Post-Intervention Activities

A post-intervention test was administered after implementation of intervention activities. The test was made up of questions, which is the same as that of the pre-intervention test. Students' response to the items were collected, scored and analyzed.

DISCUSSION

The discussion of the results will focus on answering the research questions.

Discussion of Research Question One

What is the performance of students before using demonstration method in teaching heat transfer?

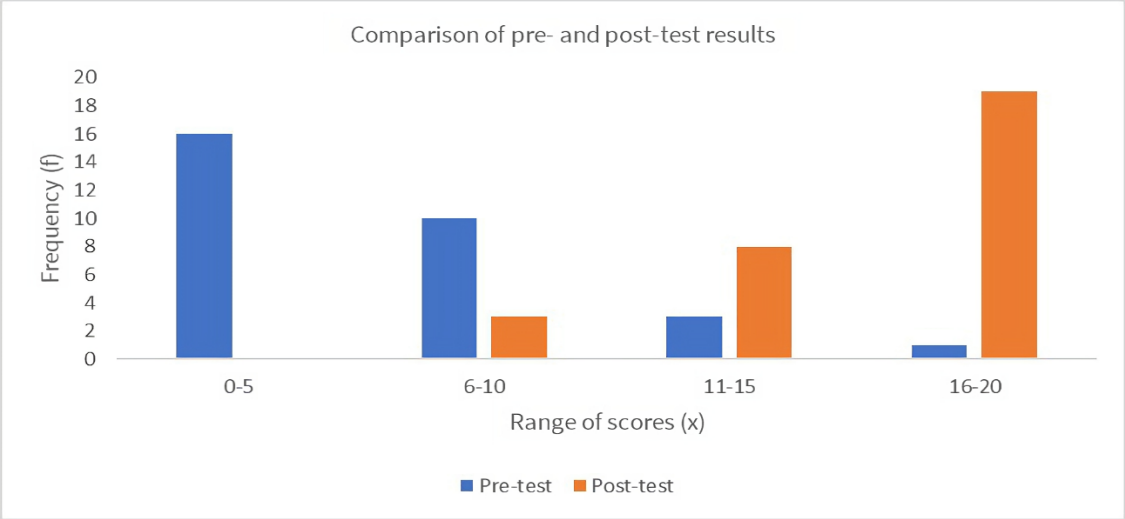

Figure 3. Bar chart of pre- and post-intervention test results (Source: Authors' own elaboration)

The findings from the pre-intervention activities (questionnaires, pre-test, and observations) identified rote learning, inadequate understanding of concepts, misapplication of formulae among others as the main factors leading to problem solving difficulties of students in heat transfer. The findings are in line with Isa et al. (2020) who aver that in our educational institutions, teachers use mainly the lecture method, which is a teacher centered method, and the implication is that learners are passive and engage in rote learning.

Discussion of Research Question Two

What is the extent of students' performance and conceptual understanding of heat transfer after the use of demonstration method in teaching?

The demonstration method was used throughout the intervention stage by both the researchers and students in teaching and learning of concepts in heat transfer. This approach has improved students understanding of complex skills and principles in heat transfer as indicated by Kola (2017) that the demonstration method is an elegant method of teaching because it improves student's understanding and retention. The improvement can also be seen from the comparison between the pre-test data and that of the post-test. The post-test saw 90% of the sample scoring above average while that of the pre-test was 13.33%. Analysis of the data clearly shows tremendous impact of demonstration method in improving the performance and conceptual understanding of students on heat transfer.

Discussion of Research Question Three

What is the perception of students after applying the demonstration method in teaching heat transfer?

The study specifically discovered "understanding of concepts" and "critical analysis" as key elements needed to enhance the problem-solving skills and performance of students. Students perceived the demonstration method of teaching as an effective method of teaching heat transfer. They further indicated that the demonstration method gave them the opportunity to fully participate, discuss and share ideas with friends, which captured their attention in physics lesson. This finding corroborates what Buncick et al. (2001) found that demonstrations encourage generalization because they promote active participation on the part of the students. Students again emphasized that the use of demonstration method of teaching has helped improve their performance in the subject.

CONCLUSION

From the study, pre-intervention activities identified rote learning, inadequate understanding of concepts, misapplication of formulae among others as the main factors leading to problem solving difficulties among students in studying heat transfer. Considering the problem under study, the study discovered understanding of concepts and critical analysis as important elements needed to enhance problem-solving skills of students. For this reason, it is incumbent and prudent on the part of students to be self-motivated and encouraged to approach the study of heat transfer with ultimate enthusiasm and less difficulties. This would be achieved if instructors employ student oriented methods such as the demonstration method in teaching heat transfer in physics. For effective teaching and learning of heat transfer at the secondary school, it is expedient on the part of teachers to employ demonstration method in their teaching because of the enormous benefits accompanying its use. This will also help arise students' interest, improve class participation and improve learning and performance in heat transfer.

Areas for Further Research

Physics is an important aspect of science and technology; therefore, a solid foundation should be laid at SHS level of the educational system. Further research should be conducted into the learning styles that students adopt in their studies.

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Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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