Visualization and simulation for effective teaching of basic thermal concepts for grade nine

MULUGETA HABTE GEBRU

Department of Physics, College of Natural Science
Arba Minch University
Ethiopia
mulugeta1970@gmail.com

ABSTRACT

This research was designed to examine Grade 9 learners' temperature and heat conceptual development during problem solving using visualization assisted teaching method as well as conducting practical work using computer simulation-based teaching method. The correlation analysis revealed that visualization assisted teaching method has advantage in bringing better problem solving performance but simulation-based teaching method didn't bring better experimentation performance due to experimentation activities limitation. The analysis based on think aloud protocol and verbal responses revealed that students in the experimental group were able to use visualization tools such as models, drawings, graphs, symbols to represent phenomena in order to develop basic science and mathematical conceptual understanding during problem solving and experimental tasks about heat and temperature. The questionnaire about learning gains revealed that lessons conducted by visualization assisted and simulation-based instruction brought better understanding of basic thermal concepts and relationships between the basic thermal concepts.

KEYWORDS

Visualization, computer simulation, performance, practical work

RÉSUMÉ

Cette recherche a été conçue pour examiner le développement conceptuel de la température et de la chaleur des apprenants de 9e année pendant la résolution de problèmes à l'aide d'une méthode d'enseignement assistée par visualisation ainsi que pour effectuer des travaux pratiques à l'aide d'une méthode d'enseignement basée sur la simulation informatique. L'analyse de corrélation a révélé que la méthode d'enseignement assistée par visualisation a l'avantage d'apporter de meilleures performances de résolution de problèmes, mais la méthode d'enseignement basée sur la simulation n'a pas apporté de meilleures performances d'expérimentation en raison de la limitation des activités d'expérimentation. L'analyse basée sur le protocole de réflexion à voix haute et les réponses verbales a révélé que les étudiants du groupe expérimental étaient capables d'utiliser des outils de visualisation tels que des modèles, des dessins, des graphiques, des symboles pour représenter des phénomènes afin de développer la science fondamentale et la compréhension conceptuelle mathématique lors de la résolution de problèmes et de tâches de l'expérimentation sur la chaleur et la température. Le questionnaire sur les gains d'apprentissage a révélé que les leçons menées par l'enseignement assisté par visualisation et basé sur la simulation ont permis de mieux comprendre les concepts thermiques de base et les relations entre les concepts thermiques de base.

MOTS CLÉS
Visualisation, simulation par ordinateur, performance, travaux pratiques

INTRODUCTION

The recent emergence of modern audio-visual media and information technologies, their applications in teaching and learning raise challenges and opportunities (UNESCO, 2000). According to this document there is a basic question to be considered what instrument could be more relevant and more useful that comprehensively improving the actual ability so that the students can obtain systematical experimental theoretical techniques and complete skills? According to Vygotsky as it was mentioned in the document (UNESCO, 2000), knowledge acquisition and conceptual change take place through a process of formulation, reformulation, and reinterpretation of knowledge. The learner is an active constructor of his/her own knowledge, and the process of knowledge acquisition is greatly assisted by interactions with peers and in particular with a teacher acting at the zone of proximal development.

Visualization is to do with Visio-spatial materials because visualization is the ability to manipulate visual patterns and identify mental images (Lohman, 1979 cited in Plass, Moreno, & Brünken, 2010). It will be extremely difficult to make a visualization that pleases and facilitates learning for all students in a class (Johansson, 2014). Whenever a student engage with problem representation (visualization) and problem solution what may happen is if problems differ in terms of structure, complexity, and context, then so too the kind of problem solving processes (Jonassen, 2004). Based on the work of Cruz (2005) physicists are able to look at problems in different perspectives, with each perspective providing different types of information about the problem situation. Problem situation can be thought in terms of words, diagrams, graphs, and equations. Ibrahim and Rebello (2013) concluded to teach how to use representational skills of an expert we should promote the construction of mental model which is evidence of understanding by designing representation-rich (multiple-representation) teaching and learning materials as well as an environment with particular emphasis placed on the key role of visual representations for reasoning, conceptual-sense making, and interpretation.

Physics should deal with ideas in the form of models, metaphors, or analogies in physical or experiential models. Kotsari and Smyrnaiou (2017) demonstrated that the interaction of students with modeling software was instrumental in creating scientific meanings. A well-designed experimental task will show the basic physical quantities (heat quantity, heat transfer, and change of state) in a simple form, helpful for students to establish a physical image of abstract concepts, contributing to understanding and mastering of the concept and laws. Likewise well-designed science laboratory can provide the sorts of experiences necessary to correct misconceptions and to develop useful physical insight. It is one of the few places where students can actually involve themselves in the processes of science: students gain first-hand understanding of physical phenomena, construct for themselves the theories needed to comprehend the physical world and express their own questions, further engaging them in the learning process.

Bezen, Bayrak and Aykutlu (2017) pointed out that physics is generally considered to be a difficult and teaching in physics classrooms should be carried out in accordance with constructivist teaching approach. Moreover, students' previous knowledge and the incorrect information they acquire during the teaching of the subject results in misconceptions (Kubsch et al., 2020), in order to prevent it and provide a meaningful and permanent learning, students previous notions (such as misconceptions) should be questioned and addressed.

Research associated with matters of comprehension of concepts and phenomena relative to heat and temperature has yielded interesting results concerning children's mental representations stretching from preschool to their graduation from school. The essential problems that students have, most importantly understanding the general framework of thermal equilibrium, lead to a wide range of comprehension difficulties and misconceptions (Elwan, 2007; Kaliampos & Ravanis, 2019; Harrison, 1996; Suliyanah, Putri, & Rohmawati, 2018; Thomaz et al., 1995; Zimmermann-Asta, 1990):

- Confusion between the concepts of heat and temperature.
- Ambiguity about the thermal relationship between an object and its environment the perception of 'cold' and 'hot' as distinct entities.
- The recognition of temperature as an internal property of a body
- As long as a body of water is heated, it's temperature rises.
- The connection between the state of the materials and their temperature.
- A substance's temperature cannot exceed it's boiling point.
- The ice's temperature is unchangeable.
- The existence of hot and cold bodies by nature.
- Vaporization, liquefaction, solidification and melting are all terms exclusively related to water,
- The materials' freezing point is 0°C and their vaporization temperature is 100°C
- During changes in state of matter temperature is fixed.
- For expansion and contraction there is ambiguity in the relationship between the volume of objects and the role of atoms or molecules.
- Confusion of heat flow between points with different temperatures.
- Difficulties related to heat conduction mechanisms.

Based on these difficulties, significant research has been carried out in which teaching interventions have been implemented in order to overcome the obstacles and form models in students' thinking that are compatible with school science knowledge (Gönen & Kocakaya, 2010; Haryono et al., 2021; Kambouri et al., 2019; McIldowie, 1998; Maskur et al., 2019; Priyadi et al., 2019; Tin, 2018; Yeo & Zadnik, 2001).

Computer application in problem solving and experimentation activities through virtual reality allows the expression of abstract reality, the presentation of abstract visual experiences that can induce students' imagination and enhance the creative concepts to develop various feasible, unique, and novel creative concepts (Hu, Wu, & Shieh, 2016). Hakyolu and Ogan-Bekiroglu (2016) elucidated the role of collaborative interaction in the knowledge-argumentation association. Duran and Dökme (2016) argued that when students are given enough time and encouragement, most students ask questions and try to answer questions asked of them. Hence teachers should encourage their students to ask questions and allow sufficient time for them to think about questions posed.

The problem during learning of the concept of temperature and heat is that most students may try to understand science on the basis of their experience in their daily lives (alternative frameworks) instead of critical thinking and logical reasoning skills (Nertivich, 2018; Ravanis, 2013; Rodriguez & Castro, 2014; Tin, 2019). Teaching with visualization tools and computer simulation strategy is also difficult, because it requires student's higher order thinking skills such as evaluation, interpretation and inferring. One can find students, who lack these required skills to develop scientific mental models, may fail to understand science concepts instead they may develop alternative conceptions/misconceptions.

Mayer (2002) argued that students understand when they build connections between the new knowledge to be gained and their prior knowledge. More specifically, the incoming information is integrated with existing schemas and cognitive frameworks. This study based on constructivist principles, mainly characterized by mental model theoretical framework, attempts to facilitate problem solving and experimentation process in the physics classroom and physics laboratory by using visualization and simulation tools.

Statement of the problem

We can find a fruitful way to alter the way most science courses are taught: to begin with we should emphasize on what students know, continue with what they can learn by arranging their interaction with the physical world around them, and connect this learning to the underlying principles of scientific knowledge. An instructional practice that has emerged over the last two decades began with what is commonly termed the personal constructivist model of learning, or simply personal constructivism. A personal constructivist model of learning assumes the existence of learners' conceptual schemata and the active application of these in responding to and making sense of new situations.

The traditional teacher dominated teaching method tends to suppose that one way of transmission of knowledge is possible in all situations. This assumption by itself has short comings it usually focuses on content coverage without the necessary effort to connect different physics concepts together, with no attempt to develop critical thinking or problem-solving skills. Not only do students not have an opportunity to form their own ideas, they rarely get a chance to work in any substantial way at applying the ideas of others to the world around them.

This study tries to find the way out from such pitfalls of our traditional method that is the dominant approach in our physics classroom and laboratory settings.

Objective of the research

The general objective of this study is to examine the effectiveness of visualization and simulation on problem solving and experimentation tasks in learning heat and temperature in terms of qualitative learning gains. The specific objectives are to address the research questions.

Research questions

1. Are there any significant differences on problem solving-skills as a result of Visualization strategies in terms of qualitative learning gains?
2. Are there any significant differences on experimentation-skills as a result of visualization simulations in terms of qualitative learning gins?

METHODOLOGY

In considering methods used in problem-solving research, the two basic categories of techniques—quantitative or qualitative—employed are the same as those used in other areas of educational research. This study employed mainly the think-aloud protocol analysis where the researcher interferes minimally and verbal analysis where the researcher probes for self explanations. The quantitative techniques often use paper and pencil tasks, such as open-ended problems, with relatively large samples. What tends to be different in the problem-solving work is the subject matter and the types of tasks used.

Description of the sample

The experimental group was sampled to include N = 49 number of students out of which M (male) = 32 and F (female) = 17 and the control group was sampled to include N = 50 number of students out of which M (male) = 33 and F (female) = 17. It should be noted that all the available sections of ninth grade were sampled. The same teacher taught both groups on the chapter about temperature and heat.

Visualization-assisted vis-a-vis simulation assisted teaching method

Visualization assisted vis-à-vis simulation assisted teaching method are designed and applied in a constructivist learning environment. It is clearly student-centered and preliminary concerned with bringing about deeper conceptual understanding and conceptual change in students. The conventional instructive teaching method is more teacher-centered and concerned with effective transmission of information and skills from teacher to the learner.

The ninth grade physics text book includes the concept of temperature and heat in a chapter. The chapter mainly focuses on measuring temperature and heat as physical quantities, thermal expansion, heat exchange, and change of phase. Table 1 contains with different representations.

TABLE 1

Basic thermal models

No	**Conceptual models**	**Mathematical models**
1.	Heat and temperature are manifestations of molecular motion and configuration.	$Q = mc\Delta T$
2.	Thermal expansion occurs as a result of temperature raise where the particles of the substance gains kinetic energy and so move more rapidly.	$Q = \Sigma E_k + \Sigma U$
3.	Heat transfer depends on thermal conductivity of a solid, mass transport in a gas and liquid, and emission and absorption of radiant energy.	Heat current = $J_q(x,y,z)\ \alpha\ -(\Delta T/\Delta x, \Delta T/\Delta y, \Delta T/\Delta z)$ α is proportionality constant
4.	The more we heat up a substance the bonds between the particles in the substance are broken and the potential energy of the particles increases, the substance changes phase (state).	Latent heat of fusion = $Q = mL_f$ Latent heat of vaporization = $Q = mL_v$

During problem solving task

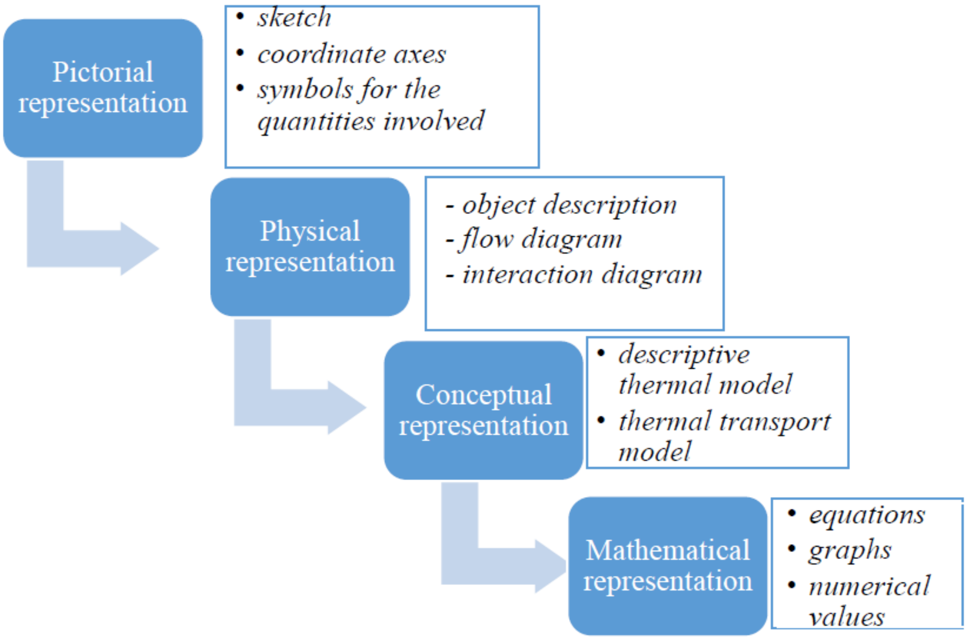
The teacher guide was prepared for this research purpose which discusses the tasks to be performed through visualization assisted teaching method on topics about heat quantity, heat transfer and change of state. The teacher for experimental group was trained how to use the intervention in the guide. The intervention is visualization assisted teaching depicted by this schematic model in Figure 1.

Visualization assisted teaching methods is applied in problem solving tasks so that students can grasp basic ideas and extend their imagination to complex problem situations in order to make connections through developing models, hypotheses and generalizations.

What we need to do in visualization assisted teaching method is engaging a learner with problem solving tasks to

- represent it in multiple representations,
- extract information from a representation,
- move in between and connect representations.

FIGURE 1



Schematic depiction of visualization assisted teaching method for problem solving task

Strategy 1: Draw a simple diagram to represent the system

Common thermometers are made of a mercury column in a glass tube and our system is the mercury in the glass tube. Students observed Celsius scale labeled for different temperature values. They were allowed to indicate the value of room temperature and one's own body temperature as measured by the thermometer.

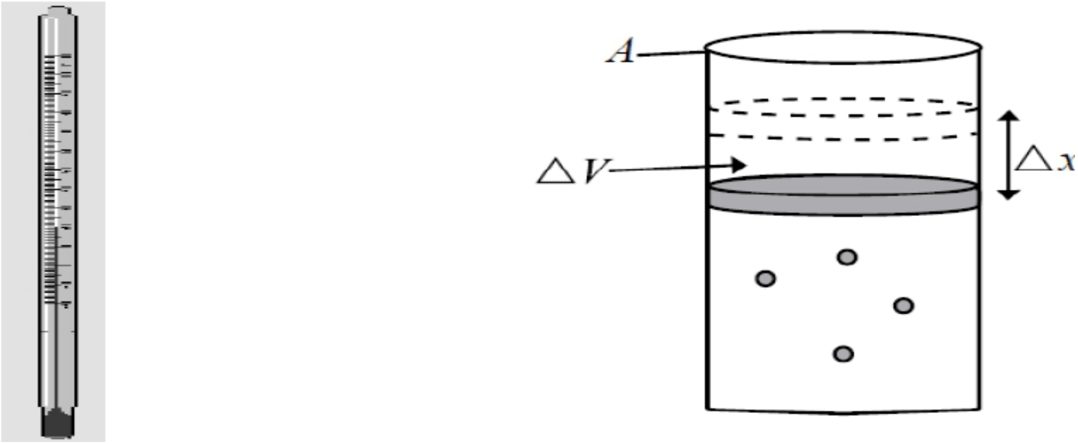
Question posed: Based on the operation of the thermometer, which has the largest coefficient of linear expansion, glass or mercury? Is there relation between the linear expansion of the mercury and the reading of the thermometer?

From this problem solving task, it is expected that such firsthand experience helps them to engage with abstract concepts like thermal expansion in more sensible and practical way. While doing these activities through demonstration, some students could face also scale-reading problems, where they could not read the scale correctly. In this case the teacher should guide them.

The purpose of posing questions is to put them into challenging situations. After getting a lot of responses from the students it is better to realize that different substances like mercury and glass do have different coefficient of expansion that exceeds for mercury compared to glass. That leads students to understand thermal expansion depends on the nature of the substances.

Strategy 2: write down relevant equations and indicate the data on the diagram
Question posed: What is the relationship between heat (Q) and temperature (T)?
It is better to start with the pictorial representation of heating a liquid in a beaker (the system) in Figure 2.

FIGURE 2



(a) Common thermometer (b) heating water in a beaker

Thermal expansion of mercury in the glass tube of common thermometer and a liquid in a beaker

There is analogy students can infer from the expansion of mercury in the glass tube they observed in the previous problem solving task. The students can now relate change in volume (ΔV) and change in length (Δx) with change in temperature (ΔT) through mathematical representation.

$$\overset{\Delta T}{\rightarrow}\ \textit{increase in temperature} \xrightarrow{yields} \overset{\Delta x}{\rightarrow}\ \textit{increase in length}$$

Visualization assisted teaching methods is used to make connections through developing models, hypotheses and generalizations. Thus, some students may say “yes” while others may say “no”, depending on whether they are considering the liquid or the beaker. In this way, a debate can be generated among students. Finally, they should confirm that different substances have different coefficient of expansion (α) and accordingly they get short expression

$$\Delta x = \alpha x_o \Delta T$$

That relates change in length (Δx) with original length (x_o) and change in temperature (ΔT).

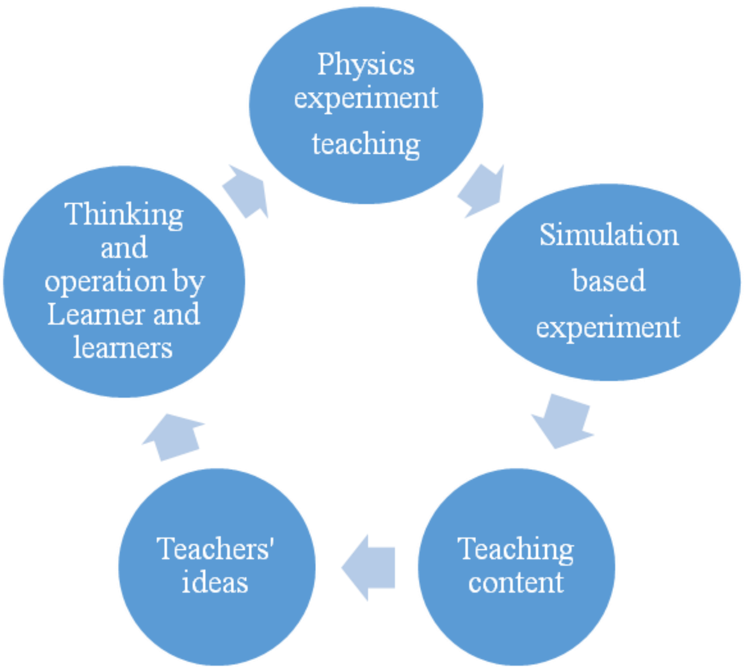
Strategy 3: Analyze the problem in terms of physics principles and identify the unknown variable
Based on the textbook the following physics principles are discussed, accordingly in solids the molecules are strongly held by electric interaction between the molecules. In liquids the molecules are still very close to each other, but the interaction is not strong enough to keep the molecules at equilibrium position. In a gas the interaction energy is small compared to the average kinetic energy of the molecules.

Teaching heat and temperature through visualization assisted teaching method is quite challenging, because these are abstract concepts. Student are expected to make the common hypothesis that 'temperature is directly proportional to speed of molecules'. However, making a common hypothesis is challenging for the students, because within the groups different students could develop different statements that seemed more like predictions rather than hypothesis. Thus, there should be debates within the groups as well as across the groups till all the students mutually agree on the above hypothesis. To learn abstract concepts by working in groups and generating discussion is fruitful, because through debate they learn that a hypothesis is a tentative explanation of phenomena. Meanwhile realizing that the debate requires a lot of time, please intervene and act as a guide, sometimes as a facilitator and mentor and as a classroom teacher. Finally, students should understand the greater temperature rise is because of greater translational kinetic energy of the molecules.

During experimental task

The teacher guide was prepared for this research purpose which discusses the tasks to be performed through simulation based teaching method on three experiments about calorimetric, heat of fusion, heat of vaporization. The teacher for experimental group was trained how to use the simulation software during the intervention. The intervention is the simulation based teaching depicted by this schematic model in Figure 3.

FIGURE 3



Schematic depiction of simulation based teaching method for experimental task

Let us focus on sample experimental task on measuring the exact temperature on the water in beaker as shown in figure 2. Please provide students with the necessary materials for demonstration activity. This activity should be done by small group of students(1 to 5 group members).

Strategy 1: Analyze the problem in terms of physics principles and identify the unknown variable.

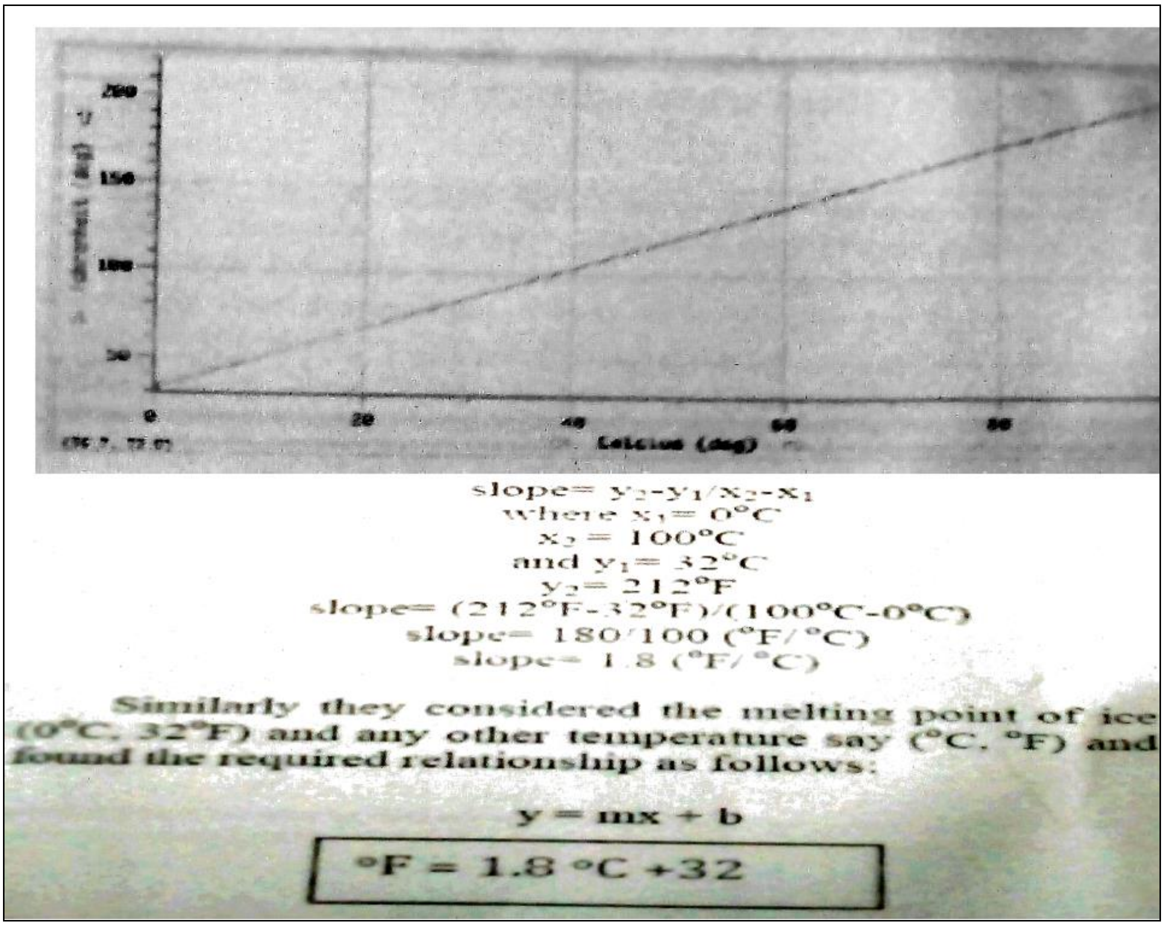
The teacher should initialize and ignite group discussion and debate through posing questions like "what are the extreme points on both the Celsius and Fahrenheit scales? "How will you deduce the relationship between ^{o}C and ^{O}F from the graph?"

For this purpose, give the students ten minutes to discuss among themselves in group and represent the relationship on a graph. Initially, some of the students may be confused how to plot a graph without numerical values. They should note that the extreme values are (0 ^{0}C, 32 ^{0}F) and (100 ^{o}C, 212 ^{0}F). Then ask them to plot the graph by using these extreme values and deduce the relationship between ^{0}C and ^{0}F by using the concept of slope to find

$$0_F = {}^{9}/_{5}\ 0_C + 32$$

As we can see the task in Figure 4 demands an integrated approach, where strong mathematical skills as well as a strong understanding of physics. This gives students conceptual and procedural understanding.

FIGURE 4



Students' sample representations for problem solving task

Students should understand that temperature is a relative quantity. Consequently, students should know that the concept of absolute zero and accept that at absolute zero molecular energy cannot be zero. Note that the assumption the energy is zero at absolute zero is incorrect.

Strategy 2: Thinking and operations through substituting variables, solving and interpreting

Experimental task: Determine specific heat of sample object(c) where water has c_w = 4186 J/kg. ^{0}C.

The activity begins with the elicitation of students' ideas about heat exchange. The purpose of elicitation through conceptual activities is to know students' prior understanding as well as to inform them about the objectives of the experimental task.

Students in a small group should record and tabulate measured values according to the built-in procedures set-in the software (Source: Richard, nd) found in Figure 5.

FIGURE 5

Observation No.	Quantities	Measured values
		
1.	Ti = initial temperature of the object + hot water	57 ^{0}C
2.	m_1 = mass of cold water	0.075 kg
3.	T_{iw} = initial temperature of cold water	20 ^{0}C
4.	m_t = mass of cold water + the object	0.22 kg
5.	T_f = cold water + the object	27 ^{0}C

Calculation of specific heat capacity of the object

$Q_{gained\ by\ water} = Q_{lost\ by\ object}$

$m_w c_w (T_f - T_{iw}) + m_o c_o (T_f - T_{io}) = 0$

<Student draws a picture here>

Assumptions:

1) The system is the object and water only but not the calorimeter.

2) No heat is lost to the calorimeter by the system. If it is, T_f will be less than it would have been. So the specific heat will be less than the real value.

3) No heat is lost to the air when we transfer the hot object. If heat is lost our T_{in} is more than the real T_{io}. Specific heat will be less than the actual value.

$m_w c_w (T_f - T_{iw}) = -m_o c_o (T_f - T_{io})$

$(0.075kg)(4186J/kg/^\circ C)(27^\circ C - 20^\circ C) = -(0.22kg)(c_o)(27^\circ C - 57^\circ C)$

$c_o = 332.9 J/kg/C$

Students' sample experimental task

Question posed: from these results, what can you conclude?

Thinking and operations through substituting variables, solving and interpreting the result in group should be done to apply conceptual models in Table 1.

RESULTS

The results of correlation of performance assessment and posttest scores

The problem solving activities were frequently set in tutorial classes and as predicted there was significant correlation between scores of problem activities and posttest scores, r = .322 and p-value .0024 < .05 as shown in Table 2. The problem solving activities were always subjected to a timely formative assessment and feedback. The students were not experienced enough during the implementation of experimentation activities and experimentation activities were not done exhaustively as a result no significant correlation was found between scores of experimentation activities and posttest scores.

TABLE 2

Correlation between performance assessment and performance post-test scores

	R	p-value
Correlations between posttest and problem solving activities	.322	.024
Correlations between posttest and experimentation activities	-.086	.604

The results of think-aloud protocol and verbal analysis

The results of think-aloud protocol and verbal analysis in Table 3 are demonstrated during problem solving and experimentation tasks performed by the experimental group students taught by visualization and simulation assisted instruction.

TABLE 3

Demonstrated strategies during problem solving and experimental tasks

<table>
<tr><th></th><th>Component strategies</th><th>Detail of the strategy</th><th>Qualitative learning gains</th><th>Results from performance scoring rubrics</th></tr>
<tr><td>1</td><td>Elaboration (in the first 15 minutes of the tutorial and lab. Class)</td><td>• Forming associations and images
• Using memory techniques (underlining, paraphrasing, Summarizing etc.)
• Creating analogies
• Questioning</td><td rowspan="2">1) Conceptual understanding of some topic areas
2) An understanding of the behavior of the physical world in some topic areas (preferably through experimentation)
3) Mathematical skills and knowledge in some topic areas
4) Recognize equations as functional relationships</td><td rowspan="2">Adequately demonstrated the ability to understand the problem and operate calculations based on visualized pathways to get solutions</td></tr>
<tr><td>2</td><td>Organization (in the next five minutes of the class)</td><td>• Selecting main ideas
• Outlining
• mapping
• Grouping</td></tr>
</table>

3	Modeling (in the next 15 minutes of the class)	• Physical model • Conceptual model • Mathematical model	5) Rates of change 6) Understanding descriptions and representations in some topic areas 6.1 Pictorial 6.2 graphical 6.3 Diagram 7) Model construction in some topic areas 7.1 Specific modeling techniques and use 7.2 use modeling in problem solving and practical activities	Adequately demonstrated the ability to identify variables and their relationship and perform experiments.
4	Evaluating (in the next five minutes of the class)	• Checking and backtracking • Revising goals and strategies • Reviewing • Assessing • Reflecting • Judging		Adequately demonstrated the ability to decide in order to make valid conclusion + the ability to make reasonable judgments

In the first place, the teacher was expected to have expert level of knowledge of the subject matter content inherent in the lesson. This fact that was evident from the educational background of the instructor and from the communications made during the study. The follow up reports as means of communication revealed that the teacher responsibly demonstrated the skills that were used to uncover misconceptions which hinder students' to solve the problems. Teachers who meet this description are able to see quickly what students are trying to say, how it connects with science or math concepts, and bring up questions, ideas or examples that help the student clarify their own thinking. The learning progression sought in each tutorial session should be determined through the level of sophistication of the problem solving activities. The follow up reports were instrumental to inform the instructor for sustainable application of these things during the study. The performances on the problem solving and experimental tasks were assessed based on the scoring rubrics in order to indicate the level of expertise of students in problem solving and experimental tasks. The information extracted from the scoring rubrics was also used for constructive feedback.

The training for experimental instructors helps for successful outcome of the study. It was observed that as part of the intervention the teacher encouraged students in a group to use a variety of means (models, drawings, graphs, symbols, etc.) to represent phenomena based on basic models. The lesson learned in the course of the study is that multiple forms of representation allow students to use a variety of mental processes to express their ideas, analyze information and to critique their ideas. The teacher should be smart enough in selecting and providing different real world phenomena as teaching tools to help students understand basic science and math concepts. For example, several different kinds of graphs could be used, not just one kind. When students in small group work on such situation it was possible to create classroom interaction and cognitive engagement as instruments in gaining meaningful learning in a series of the whole tutorial and lab sessions covered in the study.

Results in terms of learning gains

The overall impact of the intervention as reported by both the students and the teacher as revealed by the questionnaires was positive since it was helpful for students learning about basic thermal models.

i) How much did each of the following aspects of the class help your learning about basic models in heat and temperature?

TABLE 4

Percentile of students' response in the first category

	No help	Helped a little	Helped	Helped a good deal	Helped a great deal
1. The class's focus on answering real world questions	19.35%	45.16%	12.9%	3.23%	19.35%
2. How the class activities, labs, reading, and assignments fitted together	0%	38.7%	38.7%	6.45%	16.13%
3. Group works in class	16.13%	9.7%	25.8%	25.8%	22.58%
4. Lab reports		12.9%	12.9%	32.26%	16.13%
5. The feedback you got	29%	32.26%	9.7%	9.7%	22.58%
6. Use of computer	3.23%	35.48%	16.13%	19.35%	22.58%
7. Class activities for each week		22.58%	41.94%	29%	6.45%
8. working with the teacher	12.9%	38.71%	19.35%	16.13%	22.58%
9. working with peers	9.68%	12.9%	38.71%	16.13%	25.81%
10. The way that the classes were taught over all	6.45%	19.35%	35.48%	22.58%	16.13%

It was evident in Table 4 that the percentile of students who rated the given feature of the class from 'helpful somewhat' to 'helpful á great deal' on the Likert scale is as follow: weekly activities (77%), the group work (74%), peer assistance (74%), lab report (61%), computer utility (58%) among others with lower percent.

ii) As a result of your work in this course, how well do you think that you now understand each of the following?

TABLE 5

Percentile of students response in the second category

	Not at all	Just a little	Somewhat	A lot	A great deal
1. Basic thermal models	25.81%	12.9%	32.26%	6.45%	25.81%
2. Laws and principles in thermal physics		38.71%	29%	16.13%	19.4%
3. Multiple representation (e.g. graphs/plots)	6.45%	41.9%	22.58%	12.9%	9.7%

It was evident in Table 5 that the calculated percentiles of students were 64.5%, 64.5%, and 45% who responded to have understood basic thermal models, laws & principles, and multiple representations respectively that were considered as indicators of learning gains due to the course. It should be noted that the calculated percentiles were based on the responses on the scale from the interval rated 'understand somewhat', to the next rated as 'understand a lot', to the last rated as 'understand a great deal' and the rest percentile of responses go to the lower degree including 'understand nothing'.

iii) How much has this class added to your skills in each of the following?

TABLE 6
Percentile of students in the third category

	No thing	Just a little	Somewhat	A lot	A great deal
1. Solving problems	6.45%	38.71%	22.58%	22.58%	9.68%
2. Designing lab experiments		9.68%	38.71%	29%	22.58%
3. Finding trends in data	3.23%	6.45%	29%	45.16%	9.68%
4. Working effectively with others	6.45%	35.48%	9.68%	29%	22.58%
5. giving oral presentation	6.45%	51.6%	12.9%	12.9%	19.35%

It was evident in Table 6 that the percentile of students who rated that they acquired skills from 'somewhat' to 'á great deal' on the Likert scale is as follow: designing lab experiments (90%), finding trends in data (83.8%), working cooperatively (61%), problem solving (54.8%) and oral presentation (45%) in the decreasing order and the rest percentile of responses go to the lower degree including 'acquired nothing'.
iv) To what extent did you make gains in any of the following as a result of what you did in this course?

It was again evident that 61%, 67.7%, and 58% percent of students responded respectively that they gained understanding of main concepts, relationships of concepts, and their connection to other subjects due to the course. It should be noted that the extent of the gain ranges for the interval rated as 'somewhat', to the interval rated 'a lot', to the last interval rated 'a great deal'. Despite the fact that 51.6%, 51.6%, and 48% of students responded below the interval rated as 'somewhat', respectively on the relevance of physics, the nature of physics, and the method of physics.

In the past, sources with similar findings such as the investigation carried out by Kozhevnikov, Motes and Hegarty (2007) pointed out conceptual knowledge, spatial ability is particularly related to solving problems and experiments. It was suggested by Kurnaz and Arslan (2014) that the use of multiple representations such as tables, data-meaning tables, conceptual change texts, concept maps and analogies can serve to improve conceptual understanding about the energy concept. The focus of the paper by Bimba et al. (2013) was to demonstrate how students' understanding of a physics problem can be improved by guiding them towards a better representation of the problem. The aim is to develop a learning tool that can assist students or novices to identify known, unknown, and latent features of the physics problems based on their knowledge and the major concept involved.

CONCLUSION

The correlation analysis revealed that visualization assisted teaching method has advantage in bringing better problem solving performance but simulation-based teaching method didn't bring better experimentation performance due to experimentation activities limitation. The analysis based on think aloud protocol and verbal responses revealed that students in the experimental group were able to use visualization tools such as models, drawings, graphs, symbols to represent phenomena in order to develop basic science and mathematical conceptual understanding during problem solving and experimental tasks about heat and temperature. The questionnaire about learning gains revealed that lessons conducted by visualization assisted and simulation-based instruction brought better understanding of heat and temperature concepts and relationships between the basic thermal concepts.

REFERENCES

Bezen, S., Bayrak, C., & Aykutlu, I. (2017). A case study on teaching of energy as a subject for 9th graders. *European Journal of Science and Mathematics Education, 5*(3), 243-261.

Bimba, A., Indris, N., Mahmud, R., Abdullah, R., Abdul-Rahman, S.-S., & Bong, C. H. (2013). Problem representation for understanding Physics problem. *Research Notes in Information Science, 14*, 621-625.

Cruz, C. (2005). *Strategies for development of student problem solving skills in the high school physics classroom*. USA: Western Michigan University.

Duran M., & Dökme, I. (2016). The effect of the inquiry-based learning approach on students' critical thinking skills. *Eurasia Journal of Mathematics, Science & Technology Education, 12*(12), 2887-2908.

Elwan, A. (2007). Misconception in Physics. *Journal of Arabization, 33*, 77-103.

Gönen, S., & Kocakaya, S. (2010). A cross-age study on the understanding of heat and temperature. *Eurasian Journal of Physics and Chemistry Education, 2*(1), 1-15.

Hakyolu, H., & Ogan-Bekiroglu, F. (2016). Interplay between content knowledge and scientific argumentation. *Eurasia Journal of Mathematics, Science, & Technology Education, 12*(12), 3005-3033.

Harrison, A. (1996). Student difficulties in differentiating heat and temperature. *Paper presented in 21st Annual Conference of the Western Australian Science Education Association*, Perth, November, 1996.

Haryono, H. E., Aini, K. N., Samsudin, A., & Siahaan, P. (2021). Reducing the students' misconceptions on the theory of heat through cognitive conflict instruction (CCI). *AIP Conference Proceedings, 2330*, 050001.

Hu, R., Wu, Y., & Shieh, J. (2016). Effects of virtual reality integrated creative thinking instruction on students' creative thinking abilities. *Eurasia Journal of Mathematics, Science, & Technology Education, 12*(3), 477-486.

Ibrahim, B., & Rebello, S. N. (2013). Role of mental representations in problem solving: Students' approaches to non directed tasks. *Physical Review Special Topics-Physics Education Research, 9*, 020106.

Johansson, J. (2014). Pedagogical vizualization of a non-ideal Carnot engine. *Journal of Thermodynamics, 2014*, 217187.

Jonassen, D. H. (2004). *Learning to solve problems: An instructional design guide*. USA: Pfeifer-Wiley.

Kaliampos, G., & Ravanis, K. (2019). Thermal conduction in metals: mental representations in 5-6 years old children's thinking. *Jurnal Ilmiah Pendidikan Fisika 'Al-BiRuNi', 8*(1), 1-9.

Kambouri-Danos, M., Ravanis, K., Jameau, A., & Boilevin, J.-M. (2019). Precursor models and early years Science learning: a case study related to the mater state changes. *Early Childhood Education Journal, 47*(4), 475-488.

Kotsari, C., & Symrnaiou, Z. (2017). Inquiry-based learning and meaning generation through modelling on geometrical optics in a constructivist environment. *European Journal of Science and Mathematics Education, 5*(1), 14-27.

Kozhevnikov, M., Motes, A. M., & Hegarty, M. (2007). Spatial visualization in Physics problem solving. *Cognitive Science, 31*(2007), 549-579.

Kubsch, M., Nordine, J., Fortus, D., Krajcik J., & Neumann K. (2020). Supporting students in using energy ideas to interpret phenomena: The role of an energy representation. *European Journal of Science and Mathematics Education, 18*, 1635-1654.

Kurnaz, A. M., & Arslan, S. A. (2014). Effectiveness of multiple representations for learning energy concept: Case of Turkey. *Procedia: Social and Behavioral Sciences*, *116*, 627-632.

Maskur, R., Latifah, S., Pricilia, A., Walid, A., & Ravanis, K. (2019). The 7E learning cycle approach to understand thermal phenomena. *Jurnal Pendidikan IPA Indonesia*, *8*(4), 464-474.

Mayer, E. R. (2002). Rote versus meaningful learning. *Theory into Practice*, *41*(4), 226-232.

McIldowie, E. (1998). Introducing temperature scales. *Physics Education*, *33*, 368-372.

Nertivich, D. (2018). Concepts thermiques de base chez les élèves de 17 ans. *European Journal of Education Studies*, *4*(2), 145-154.

Plass, L. J., Moreno, R. & Brünken, R (Eds.) (2010). *Cognitive load theory*. UK: Cambridge University Press.

Priyadi, R., Diantoro, M., Parno, P., & Helmi, H. (2019). An exploration of students' mental models on heat and temperature: A preliminary study. *Jurnal Penelitian Fisika dan Aplikasinya*, *9*(2), 114-122.

Ravanis, K. (2013). Mental representations and obstacles in 10-11 year old children's thought concerning the melting and coagulation of solid substances in everyday life. *Preschool and Primary Education*, *1*(1), 130-137.

Richard, W. T. (nd). *Physics laboratory simulator*. Saint Mary's College. Retrieved from www.saintmarys.edu\~rtarara\software.html.

Rodriguez, J., & Castro, D. (2014). Children's ideas of changes in the state of matter: Solid and liquid salt. *Journal of Advances in Humanities*, *1*(1), 1-6.

Suliyanah, S., Putri, H. N. P. A., & Rohmawati, L. (2018). Identification student's misconception of heat and temperature using three-tier diagnostic test. *Journal of Physics: Conference Series*, *997*, 012035.

Thomaz, M. F., Malaquias, I. M., Valente, M. C., & Antunes, M. J. (1995). An attempt to overcome alternative conceptions related to heat and temperature. *Physics Education*, *30*, 19-26.

Tin, P. S. (2018). Élaboration expérimentale des représentions mentales des élèves de 16 ans sur les concepts thermiques. *European Journal of Education Studies*, *4*(7), 141-150.

Tin, P. S. (2019). Un cadre méthodologique pour la démarche d'investigation : L'exemple du changement d'état de l'eau à l'âge de 8 ans. *European Journal of Education Studies*, *6*(4), 1-12.

UNESCO. (2000). *Prospects: the quarterly review of comparative education*. XXIV, 3/4, 471-485.

Yeo, S., & Zadnik, M. (2001). Introductory thermal concept evaluation: Assessing students' understanding. *The Physics Teacher*, *39*, 495-504.

Zimmermann-Asta, M.-L. (1990). *Concept de chaleur: Contribution à l'étude des conceptions d'élèves et de leurs utilisations dans un processus d'apprentissage*. Thèse de doctorat, Genève: FPSE-Université de Genève.