Teachers' Knowledge, Attitude and Practices on Visualization Techniques in the Teaching-Learning of Middle School Science and Mathematics Subjects in Ethiopia

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Abstract

This study assessed teachers' knowledge, attitude and practices of visualization techniques in the teaching-learning of science and mathematics subjects in middle schools in Ethiopia. The study employed survey study design. Quantitative data were collected using a self-report questionnaire from 151 middle school science and mathematics teachers selected from two regional states and one city administration of Ethiopia using cluster sampling method. Qualitative data were also generated using interview in order to augment the quantitative data. Both quantitative and qualitative analyses were used to make meaning of the collected data. Results indicated that science and mathematics teachers' knowledge, attitude and practices in implementing visualization techniques were below the average or expected value. There was no significant difference in teachers' knowledge, attitude, and practices of visualization in designing lessons, teaching concepts, exposing students to practice, and assessing students' progress on visualization techniques with respect to gender, qualification, and subject matter. It was recommended that schools provide the appropriate tools, teachers should be given training on how to implement them, the textbooks and teachers' handbook should be revised by incorporating the appropriate visualization techniques, and supporting the teachers in the implementation of visualization.

Keywords: Visualization, Teachers' Knowledge, Teachers Attitude, Teachers Practices, Science and Mathematics Education, Middle School

Introduction

Educational researchers have focused on visualization tools to promote student' learning because they are important in concretizing abstract concepts to help understanding of spatial relationships (Stieff, Bateman & Uttal, 2007), and illustrate an idea that words cannot describe (Linn, 2003).

Guttierrez (1996) defined visualization as a reasoning activity based on the use of visual and spatial elements, mental or physical, performed to solve problems or prove properties. Wileman (1993, p.110) also explicated visualization as "the process of graphically or pictorially representing facts, directions, processes, data, organizational structures, places, chronologies, generalizations, theories, feelings, and attitudes." Bishop (1989) further explains visualization in terms of what of (the product, object or visual image) or *how* of visualizing (the process, activity or skill).

The most commonly used types of visualization techniques for knowledge construction include concept mapping, drawing and real-life applications. Concept mapping refers to the process of geographically representing concepts and their relationships (Anderson-Inman & Ditson, 1999). According to Vekiri (2002) graphic representations allow more efficient information processing than verbal ones, and reduce the demand on working memory; and real-life applications are more concrete. Teachers should teach science and mathematics in a more ‘alive’ and ‘realistic’ ways in order to show the application of science and mathematics in everyday life, and to make science and mathematical skills ‘accessible’ to as many students as possible (Agata, 2000).

Examples, non-examples, counter examples**,** and comparison and contrast are other types of visualization techniques used to develop students’ visual ability. Examples are an integral part of mathematical thinking, generalization, abstraction, argumentation, and analogical thinking whereas non-examples are associated with conceptualization and definitions and serve to highlight critical features of a concept and counter-examples are associated with claims and their refutations (Yanuarto, 2006).

Visualization techniques also include experiment, manipulative and computer applications. Experiments have a great potential to introduce the concept of a variable and introduce science and mathematical concepts (Michelsen, 2006). Manipulative (as real objects, models or paper folding) are useful for students to see, touch, sort, take apart, and manipulate physical objects, begin to develop clearer mental images and represent abstract ideas more completely than those whose concrete experiences are limited (Heddens, 1986). Equally animation as a computer application generates a series of frames, where the sequence of frames is determined either by the designer or the user (Betrancourt & Tversky, 2000). Several findings (e.g., Catrambone & Seay, 2002) suggest that animations can be used successfully for delivering abstract contents like mathematical rules, Newton’s laws, or computer algorithms.

Review of Related Literature

Previous works by different researchers show evidences about addressing students’ conceptual understanding difficulties in learning mathematics through visualization (Duval, 2017). Visualization is a process by which mental representation can be seen to reduce the learning difficulties of students’ conceptual understanding. Yet visualization has multifaceted variables of concern that enable better learning and reduce difficulties. Kosslyn, (1996) also described visualization as the creation of a mental image of a given concept. As such and from the teaching point of view visualization seems to be a powerful method to be utilized for enhancing students’ understanding of a variety of concepts in mathematics (Rahim & Sawada, 1990). Use of visualization approach provides an opportunity for students to look at mathematics course which was seen as an accumulation of abstract structures and concepts from a different perspective.

Wu and Shah (2004) highlighted the important role of visualization in reducing how much students have to remember. Linn (2003) also found that visualization is useful for interpreting ideas. Visualization is extraordinarily useful in the initial introduction of students to learning science and mathematics as well as in their subsequent stages of the teaching and learning of science and mathematics. It also helps to enhance student verbal or textual explanations of particular scientific concepts (Gilmartin, 1982) and understanding of scientific explanations (Mayer & Anderson, 1991). In addition to that it develops student's abilities (Winn, 1988) while improving their attitude toward learning science and mathematics (Lindquist, 1980). Thus, without instruction that applies visualization techniques students often experience difficulty in interpreting concepts using three-dimensions.

Teachers' Knowledge about Visualization Techniques

Teachers should have extensive background knowledge in order to interpret visualizations (Linn, 2003) and to integrate appropriate visualization tools in teaching-learning, and their pedagogical content knowledge (Shulman, 1986). Nevertheless, teachers also need to have knowledge of the wide range of technologies available and how they support the content to be taught and the best pedagogical approaches to fit the purposes (Koeher & Mishra, 2005). But, practice showed that most teachers do not assimilate computer-skills as technologies change much faster than teachers could manage to use and prepare students to utilize them (Jasute, 2013).

Teachers' Attitude towards Visualization Techniques

The level of confidence and knowledge that teachers possess play a significant role in their attitudes toward technology (Mustafina, 2016). A lack of confidence in one's ability to use technology and a corresponding lack of commitment to using it can add to a teacher's reluctance to integrate technology into the classroom experience (Ertmer et al., 2007). Students' motivation and confidence increase when technology is integrated into classroom instruction. Computer engagement also improves student academic achievement. According to Balanskat, Blamire and Kefala (2006) teachers have a positive perception of visualization techniques but strategies for their effective use are still debatable. Bingimlas (2009) found out several advantages and barriers to the successful integration of visualization techniques where one of the barriers stated by Becta (2004) is lack of teachers' confidence. Lack of confidence also causes lack of competence to integrate visualization techniques into pedagogical practice. Mayer (2001) on his part stated that teachers demonstrated a range of positive attitude for the use of visualization in science and mathematics.

Implementation of Visualization Techniques in Teaching Science and Mathematics

Researches indicated significant positive effects of visualization on the learning achievement of students (Brandt, et. al., 2001); and students learning with visualization was more successful in conceptual understanding (Serpil et al, 2006). Despite its effect, implementing visualization in science and mathematics seeks designing lessons and exposing students to practice the visualization of science and mathematical concepts and assessing their progress on visualizing the science and mathematical concepts (Mulugeta, 2018).

Designing lessons using visualization techniques: Linn (2003) indicated that learners may be confused by scientific visualizations because they do not have the same background knowledge as the people who created the visualizations. Linn concluded that the appeal of visualizations overshadows the challenges of designing effective material. The concerns in planning were when and how to use different types of visualization in order to maximize their usefulness. To be effective visual representations must first be well designed and visualization object must effectively communicate information to the students (Linn, 2003).

Teaching science and mathematical concepts using visualization techniques: Linn (2003) further explained that instruction is important to ensure effective use of visualizations in science. Without visualization techniques students get difficulties in interpreting three-dimensional information. According to Bransford, Brown, and Cocking (1999), technology can be used to help supply five key conditions for learning such as include real-world contexts for learning; connections to outside experts, visualization and analysis tools, scaffolds for problem solving, and opportunities for feedback, reflection and revision. Graph, diagram, pictures and geometrical shape or models are a tool for visualization of the abstract concept in science and mathematics. By means of these, human reason sets up a relation between physical or external world and the abstract concepts (Konyalioglu et al., 2003).

Exposing students to practice the visualization of science and mathematical concepts: Students' practice on the visualization techniques is important for the students' progress. Therefore, for science and mathematics discourse and mental image, teachers should expose students to practice the visualization of science and mathematics using external visual representation (Phillips, Norris & Macnab, 2010).

Assessing students' progress on visualizing the science and mathematical concepts: Teach students how to work with visualization objects and monitor and assess the appropriateness and effectiveness of visualizations (Cifuentes & Hsieh, 2003).

The Present Study

The quality of learning outcomes in developing countries has been poor (Word Bank report, 2013) and the Ethiopian National Learning Assessments in 2010 (MoE, 2010) and 2013 (MoE, 2013) showed that secondary students' average achievement scores in science and mathematics were very low. For example, the average National Learning Assessment result in mathematics is below

40% (below the expected 50% national standard) for Grades 4 and 8 for the years 2012, 2016 and 2020 (MoE, NEAEA, 2012, 2016, 2020).

In addition, most Ethiopian students do not understand mathematical concepts (Shishigu, 2018); have difficulties in learning and understanding basic descriptive statistical concepts and procedures (Yimam and Dagnew, 2022); have low calculus knowledge and this is due to lack of conceptual knowledge in limit of functions (Sebsibe & Feza, 2020); and they are not equipped with the necessary skills to understand basic algebraic concepts (variables, constructs and sub-constructs) as unknown quantities involved in real-life problem situations (Ketema, 2021).

The students' learning difficulty is related with acquiring the abstract nature and concept of science and mathematics. In addition, traditional science and mathematics teaching mainly cultivates skills neglecting conceptual understanding of the underlying domain (Kadijevic, 1999). These cause students to learn the concepts by memorization rather than visualizing them with understanding. One more important problem associated with the teaching of science and mathematics is students' poor understanding in establishing the relationship between their knowledge and the intuition about concrete structures and abstract nature of science and mathematics.

There are many obstacles and challenges that hinder teachers from effective implementation of visualization. Becta (2004) categorized the challenges as teacher-level (individual), such as lack of time, lack of confidence, and resistance to change, and in school-level (institutional), such as lack of effective training in solving technical problems, and lack of access to resources. Before one tries to see the broader institutional factors, it seems much better to investigate individual factors. Some researches in Ethiopia indicated that visualization technique as well as visualization technique-assisted problem-based learning were found to be useful approaches to improve students' conceptual understanding (Abera et al., 2021) and enhance students' attitude and the components of attitude on Mathematics, Geometry and Algebra (Abera et al., 2022). Moreover, the research findings of Mulat, Mulugeta, and Tadele (2021) indicated that students acquired better visualization, improved understanding, encouraged participation, promoted their team work and individual work, created enjoyable learning environment, boosted their interest, motivation and imagination about Limits using GeoGebra in a multi-teaching environment.

Regarding the effect of visualization in mathematics with respect to sex, program, level of teaching, and year of service, Mulugeta and Demiss (2019) suggested that, with the exception of designing lessons using visualization techniques on which male and female teachers held similar opinions, in the remaining cases, male and female teachers on the one hand and teachers with varying years of experience had similar perceptions. However, while Master's program teachers were significantly lower than Bachelor and PGDT teachers on the one hand, preparatory-level teachers were significantly lower than primary and secondary-level teachers on account of developing students' visualization, designing lessons using visualization techniques, teaching concepts using visualization techniques, exposing students to practice visualization of concepts, and assessing students’ on visualizing concepts. Likewise, teachers with many years of service were significantly lower than those with fewer years of service in developing students' visualization.

Therefore, the purpose of this study was to assess mathematics and science teachers’ knowledge, attitude and practices towards teaching science and mathematics using different visualization techniques. Given the importance of visualization, this study assesses teachers’ knowledge and attitude towards visualization techniques and how they implement them in the teaching of science and mathematics subjects in middle schools by answering the following questions.

1) What is the level of teachers’ knowledge and attitude towards visualization techniques in teaching middle school science and mathematics?
2) To what extent do teachers implement visualization techniques in teaching middle school science and mathematics?
3) Are there significant differences in teachers’ knowledge, attitude and practice of visualization techniques in teaching middle school science and mathematics with respect to gender, educational level, and subject area?

Methodology

Research Design

The study used a mixed survey design where data were collected from 50 middle schools in two regions and one city administration of Ethiopia.

Population, Sampling Techniques and Participants

The research sites were Addis Ababa City Administration, Amhara and Southern Nations, Nationalities, and Peoples’ Region (SNNPR). The population encompasses all teachers in these study areas. Addis Ababa has ten sub-cities, Amhara thirteen zones and SNNPR thirteen zones. For this survey, ten middle schools (one from each sub-city) from Addis Ababa, twenty middle schools each from SNNPR and Amhara were selected by using cluster sampling. All the science and mathematics teachers (n = 151) in the selected schools were considered as participants of whom 27(17.9%) were from Addis Ababa, 64(42.4%) from SNNPR, and 60(39.7%) from Amhara. By gender, 51(33.8%) were female and 100(66.2%) male teachers. Regarding educational level, 93(61.6%) have diploma while 58(38.4%) have bachelor degree. 49(32.5%) teach mathematics, 27(17.9%) physics, 36(23.8%) chemistry, and 39(25.8%) biology; and 79 (52.3%) of them teach in Grade 7 while 72(47.7%) teach in Grade 8.

Data Collection Instruments and Procedures

Data were collected using questionnaire and interview. A self-reported questionnaire adapted from Alias (2000) and Alias, Black and Gray (2002) were employed to assess teachers' knowledge, attitude and practices of visualization techniques. The number of questions for the variable teachers' knowledge of visualization techniques contains 13 items; for the variable teachers' attitude towards visualization techniques contains 20 items with its components of attitude: confidence in applying visualization techniques in teaching (6 items), usefulness of visualization techniques in teaching science and mathematics (8 items), and enjoyment in using visualization techniques in teaching science and mathematics (6 items). In addition, the variable teachers' practice in implementing visualization techniques contains 34 items with its components: designing lesson using visualization techniques (9 items); teaching using visualization techniques (9 items); exposing students to practice using visualization techniques (8 items); and assessing students' progress (8 items). The type of the questions for all items measure was on a 5-point Likert-type scale.

The adopted instrument was commented for face and content validity by professionals and was also piloted on forty-eight teachers teaching Grades 7 and 8 science and mathematics from Addis Ababa who are not included in the main study. The pilot school is far from the target schools in order to avoid contamination of knowledge about the survey. The Cronbach Alpha values from the pilot study were .831, .724, .733, .734, .817 respectively for teachers' attitude, confidence, usefulness, enjoyment, and knowledge towards teaching using visualization techniques; .953 for implementing visualization techniques in teaching; and .808, .831, .882, .916 respectively for designing lessons, teaching, exposing students to practice, and assessing students' progress using visualization techniques. These alpha values indicated that the subscales have acceptable internal-consistency. Interview guide primarily used to generate data about challenges in implementing visualization techniques in teaching science and mathematics and to support the data collected through the questionnaire. The interview guide was developed by the researchers. The questionnaire was dispatched to all the sampled teachers, and fifty teachers one from each school were interviewed. From fifty interviewed teachers, 25 were from Grade 7 and the others 25 from Grade 8; in addition, 14 were mathematics teachers and 12 each were from the sciences: physics, chemistry and biology teachers. The interviews were audio-recorded and transcribed. While conducting this research, the researchers followed the ethical conducts such as eliciting informed consent, confidentiality and privacy, adhering to beneficence's principle, practicing honesty and integrity.

Results

a) *Descriptive Statistics for Teachers' Knowledge, Attitude and Practices in Implementing Visualization Techniques*

The descriptive statistics for science and mathematics teachers' Knowledge, Attitude and Practices in implementing visualization techniques are presented in Tables 1 – 3. Table 1 presents the descriptive statistics of the science and mathematics teachers' knowledge of visualization techniques.

Table 1

Teachers' Knowledge of Visualization Techniques (N=151)

Variables: I have knowledge of	**Mean**	**SD**
applying *concept map* in my teaching.	3.91	.879
presenting *application of the topic/unit/chapter* at the beginning of a topic.	4.28	.769
giving practical application in terms of projects that are collected from a field.	3.75	.931
giving *application of a concept by examples* under each topic in class.	4.23	.883
explaining concepts using *non-examples* in my teaching.	2.79	1.30
explaining concepts using a *counter example* in my teaching.	3.97	.923
explaining concepts using *compare and contrast* in my teaching.	4.13	.854
using *analogical* representation.	3.54	1.05
experimenting the concepts practically.	3.83	1.02
explaining concepts using *real objects* in my teaching.	4.09	.959
applying manipulative(s) such as *object models/paper-folding/kits.*	3.91	1.02
applying *graphic/pictorial/diagram/chart* presentations in teaching concepts.	4.11	.990
applying *animation or simulation* using computer or software in my teaching.	2.87	1.39
Knowledge of implementing visualization techniques	**3.80**	**.510**

As indicated in Table 1, the aggregate average value of the science and mathematics teacher's knowledge of implementing visualization techniques was slightly below the agreement value 4 (mean = 3.80) with SD = .51. It is indicated that the least average of teachers' knowledge was on applying animation or simulation using computer or software (mean = 2.87) and explaining the concepts using non-examples (mean = 2.79). The highest rated teachers' knowledge was presenting application of a topic/unit/chapter at the beginning (mean = 4.28); followed by giving application of a concept by examples under each topic in class (mean = 4.23); explaining concepts using compare and contrast (mean = 4.13), applying graphic/pictorial/diagram/chart presentations in teaching concepts (mean = 4.11) and applying manipulative (s) such as object models/paper-folding/kits (mean = 4.09). For the remaining items teachers had moderate knowledge.

Teachers were interviewed regarding the visualization techniques in which they have shortage of theoretical and practical knowledge. A mathematics teacher (MT-1) reflected his view on the knowledge of visualization as follows:

I have a shortage of theoretical and practical knowledge. I know nothing about animation, simulation, video, and computer application because there is no computer in the school and no training regarding these techniques. (MT-1)

A physics teacher (PT-1) expressed his reflection about the knowledge of visualization:

I have a shortage of theoretical knowledge and skill gaps in implementing many of the visualization techniques. (PT-1)

Another physics teacher (PT-2) from a different school described:

I have little knowledge about concept maps, giving examples and non- examples but I faced challenges in implementing them (skill and practice gap). (PT-2)

A chemistry teacher (CT-1) from a different school described his understanding of knowledge of visualization techniques as follows:

I am good in using diagrams and demonstration rarely. I have limited knowledge and skill in animations/simulations and applications of the topics. However, I do not have knowledge of the different visualization techniques. (CT-1)

The above interview data are samples of teachers' responses, and others have similar views. Therefore, most of the teachers responded that they had shortage of both theoretical and practical knowledge on visualization techniques; especially on animation, simulation, video and specimen.

Table 2 presents the descriptive statistics of the science and mathematics teachers' attitude and components of attitude towards visualization techniques.

Table 2

Teachers' Attitude Towards Visualization Techniques (N=151)

Variables	Mean	SD
I am sure I understand visualization techniques.	3.97	.989
I doubt that I will improve my teaching using visualization techniques.	2.60	1.23
Visualization techniques are hard for me to apply.	3.19	1.24
I feel confident in applying visualization techniques.	3.69	1.14
I am sure I will improve my teaching using visualization techniques.	4.02	.969
I am not sure which type of visualization techniques are applied to teach a concept.	3.17	1.22
Confidence in applying visualization techniques in teaching	**3.44**	**.561**
Visualization techniques help better students' understanding of concepts.	4.01	1.12
Reasoning and problem solving are complicated using visualization techniques.	2.92	1.25
Visualization techniques do not enhance students' understanding.	3.38	1.33
Visualization techniques improve achievement of students.	4.04	.999
Visualization techniques help reasoning and problem solving of students.	4.12	.894
The results of the students decrease when using visualization techniques.	3.33	1.32
Visualization techniques enhance motivation of students' learning.	4.01	1.01
Visualization techniques enhance frustration of students' learning.	2.92	1.30
Usefulness of visualization techniques in teaching science and mathematics	**3.59**	**.674**

Variables	Mean	SD
Visualization techniques are enjoyable and stimulating to me.	4.02	.941
I am interested and willing to acquire further knowledge of visualization techniques	4.09	.926
I have always enjoyed teaching using visualization techniques.	3.89	.963
Visualization techniques make me feel uncomfortable and nervous.	3.60	1.23
I have never liked teaching using visualization techniques.	3.51	1.33
I would not like to develop my visualization techniques skills.	3.58	1.36
Enjoying the use of visualization techniques in teaching science and mathematics	**3.78**	**.780**
Attitude of teachers towards teaching using visualization techniques	**3.60**	**.576**

Table 2 indicates that teachers' attitude towards teaching science and mathematics using visualization techniques (mean = 3.60) is positive but below the agreement level (Agree = 4). Lowest result was observed in teachers' confidence to apply visualization techniques (mean = 3.44); followed by usefulness of visualization techniques in teaching (mean = 3.59); and enjoyment using visualization techniques in teaching (mean = 3.78).

The teachers had better confidence to improve their teaching using visualization techniques (mean = 4.02). The result also show that teachers believe visualization techniques are useful for reasoning and problem solving of students (mean = 4.12); improving achievement of students (mean = 4.04); helping better students' understanding of concept (mean = 4.01); and enhancing motivation of students' learning (mean = 4.01). Regarding teachers' responses on the enjoyment of visualization techniques, the highest rating was that visualization techniques are enjoyable and stimulating (mean = 4.02); and that they are interested and willing to acquire further knowledge of visualization techniques (mean = 4.09). For the other items teachers had moderate confidence on usefulness and enjoyment in the implementation of visualization techniques.

Table 3 presents the descriptive statistics of the science and mathematics teachers' practices in implementing visualization techniques in teaching.

Table 3

Teachers' Practices in Implementing Visualization Technique (N=151)

Variables:	Mean	SD
In my lesson planning, I include		
concept map and analogy to relate and clarify concepts.	3.59	.954
graphs, pictures, diagrams and charts to practice concepts.	3.96	.832
real-life applications to clarify the understanding of concepts.	3.86	.910
examples to explain concepts.	4.19	.854
non-examples/counter examples in explaining or clarifying concepts.	3.07	1.25
compare and contrast in relating and differentiating concepts.	3.79	.995
experimental activities for clarifying or proving concepts.	3.59	1.19
object models/kits/paper-folding to clarify abstract concepts.	3.56	1.14
video/animation/simulation/specimens by using computer/software applications.	2.58	1.40
Designing Lesson Using Visualization Techniques	**3.58**	**.643**

Variables:	Mean	SD
During my teaching,		
I apply *concept map and analogy* in relating and clarifying concepts.	3.54	.936
I show *graphical, pictorial, diagrammatical presentations* to clarify concepts.	3.87	.899
I show *real-life applications* of concept.	3.67	.971
I explain a concept using *examples.*	4.17	.804
I clarify concepts using *non-examples*/*counter examples.*	3.10	1.18
I use *compare and contrast* in relating concepts.	3.63	1.13
I use *experimentation* for clarifying some concepts.	3.48	1.11
I use *object models/kits/paper-folding* to clarify abstract concepts.	3.60	1.04
I show *video*/*animation/simulation/specimens* by using computer applications.	2.53	1.34
Teaching Using Visualization Techniques	**3.51**	**.660**
During a lesson,		
I ask students to practice *concept maps and analogy* of concepts.	3.68	.935
I give problems for the students in terms of *graphs/pictures* to clarify concepts.	3.67	.907
I provide *real-life applications* for the students to clarify concepts.	3.71	.949
I encourage students to produce *non-examples*/*counterexamples* of concepts.	3.14	1.20
I give activities for the students to practice *comparing and contrasting* concepts.	3.82	.872
I engage the students in the experimentation of concepts.	3.50	1.05
I engage students to produce *object models/kits/paper-folding* to clarify concepts.	3.48	1.03
I encourage students to practice *computer application* in their learning.	2.87	1.32
Exposing Students to Practice Using Visualization Techniques	**3.48**	**.683**
During a lesson or examination,		
I ask students to relate and understand concepts using *concept map and analogy.*	3.63	.991
I evaluate students' work on *graphical or pictorial* application of a concept.	3.60	.918
I assess students' work on *real-life application* problems.	3.58	1.03
I ask students to give *examples/non-examples*/*counter examples.*	3.30	1.07
I encourage students to reflect on *comparing & contrasting* of different concepts.	3.87	.814
I observe and assess students' *experimental activities.*	3.64	1.13
I observe and assess students' learning from *object models/kits/paper-folding.*	3.66	1.08
I ask students whether they understand the concepts from *computer application.*	3.03	1.39
Assessing Students' Progress	**3.54**	**.713**
Practices of implementing visualization techniques in teaching	**3.53**	**.596**

Table 3 indicates that the aggregate average value (mean = 3.53) for teachers' practices in implementing visualization in teaching-learning is below the specified mean 4. Those that caused to show lower rating were designing lessons using visualization techniques (mean = 3.58); teaching concepts using visualization techniques (mean = 3.51); exposing students to practice the visualization of concepts (mean = 3.48); and assessing students' progress on visualizing concepts (mean =3.54).

In planning a lesson, the science and mathematics' teachers frequently include examples to explain concepts (mean = 4.19) with video/animation/simulation/ specimen/computer or software applications (mean = 2.58) least implemented. All other items were moderately implemented in the designing of the lesson. In their teaching as well, the science and mathematics' teachers implement the use of examples to explain concepts (mean = 4.17) most frequently, but they implement least showing video/animation/simulation/specimens by using computer or software applications (mean

= 2.53). The other items were moderately implemented in their teaching. All visualization techniques were moderately implemented in exposing students to practice using visualization techniques; but they implemented least encouraging students to practice the animation/simulation/video/specimens/ computer application in their learning (mean = 2.87). In addition, for the assessment of the students' progress, the science and mathematics' teachers moderately implemented visualization techniques.

Teachers were interviewed regarding the different visualization techniques they implemented mostly, rarely or never at all. A biology teacher (BT-1) expressed his reflection about the practices of visualization as follows:

> *Out of the different visualization techniques mentioned, I used models and kits, specimens as visualization techniques some times in my teaching. (BT-1).*

A mathematics teacher (MT-1) reflected his view on the implementation of visualization as:

> *I used pictorial and graphics, but real- life applications, simulations/animations computer applications were not used at all in my teaching. (MT-2)*

A chemistry teacher (CT-2) from a different school described the implementation of visualization techniques as follows:

> *I implemented mostly graphical, diagrammatical, and pictorial [visualization/presentation]; and rarely used experimentations, examples/non-examples, kits, and compare/contrast; but did not implement at all animations/simulation. (CT-2)*

The above interview data are samples of teachers' responses, and all teachers' interview revealed that the visualization techniques that are mostly used in many of the schools were graphical, pictorial, and diagrammatical presentations. The least used visualization techniques were models, kits, experimentation, examples, non-examples and counter example, real objects and real-life applications, concept maps, paper folding, compare & contrast, and specimens. Animations, simulations, video, and computer applications were among the least used techniques. The reasons for not implementing these were mentioned to be lack of knowledge and resources. Large class size, lack of students' interest to learn, lack of resources, lack of appropriate training of teachers, teachers' overload and lack of laboratory equipment and materials were among the pronounced challenges detected in most schools.

b) *Teachers' knowledge, attitude and practice by gender and educational level*

In order to examine whether there is a significant difference among science and mathematics teachers' knowledge, attitude and practices in implementing visualization techniques with respect to gender and educational level, independent samples t-tests were used, since the assumptions of independence, normality of the data and homogeneity of variances were met. Even though there are significant differences in the sample size of male and female groups, we can perform an independent t-test, because equal sample size is not one of the assumptions made in a t-test. The real issues arise when the two samples do not have equal variances, which is one of the assumptions made in a t-test.

Table 4 shows descriptive statistics and independent samples t-test results for science and mathematics teachers' practices in implementing visualization with respect to gender and educational level.

Table 4

Comparison of Means of Teacher's Perceived Practice of Visualization by Gender and Educational Level

Components	Variable		N	M	SD	t	df	p
Designing the lessons using visualization techniques	Gender	Female	51	3.56	.566	-.251	149	.802
		Male	100	3.59	.681			
	Educational level	Diploma	93	3.56	.666	-.551	149	.583
		Degree	58	3.62	.607			
Teaching concepts using visualization techniques	Gender	Female	51	3.48	.636	-.171	149	.864
		Male	100	3.50	.676			
	Educational level	Diploma	93	3.44	.681	-1.61	149	.110
		Degree	58	3.62	.615			
Exposing students to practice the visualization concepts	Gender	Female	51	3.42	.598	-.867	149	.387
		Male	100	3.52	.723			
	Educational level	Diploma	93	3.43	.759	-1.36	149	.176
		Degree	58	3.58	.534			
Assessing students' on visualizing the concepts	Gender	Female	51	3.45	.698	-1.04	149	.299
		Male	100	3.58	.720			
	Educational level	Diploma	93	3.45	.756	-1.87	149	.063
		Degree	58	3.68	.620			
Implementing visualization techniques	Gender	Female	51	3.49	.545	-.548	149	.585
		Male	100	3.55	.622			
	Educational level	Diploma	93	3.47	.633	-1.52	149	.130
		Degree	58	3.62	.522			

In Table 4, the descriptive statistics shows that mean score of male teachers is better than female teachers and degree holder teachers were better than diploma holder teachers in all the variables: designing lessons; teaching concepts; exposing students to practice; assessing students' progress of learning; and practices in implementing visualization techniques. But, the table of an independent samples t-test indicated that the t-values do not reveal statistically significant difference between male and female teachers, and degree and diploma teachers. Thus, the practice of visualization technique implementation is independent of gender and educational level.

Table 5 (*on the next page*) shows descriptive statistics and independent samples t-test results for science and mathematics teachers' attitude towards teaching using visualization techniques and knowledge with respect to gender and educational level.

In Table 5 (*next page*), the descriptive statistics shows that in all the components of attitude and knowledge, female teachers were better than the male teachers, and degree holder teachers were better than diploma teachers. But the independent samples t-test result indicated that the observed differences are not statistically significant except for the confidence of teaching using visualization techniques at which degree holder teachers were significantly better than diploma teachers ($t(149) = -1.98$, $p < 0.05$). Thus, female and male teachers, and degree and diploma teachers had more or less similar attitude towards implementing visualization techniques, except for confidence.

Table 5

Comparison of Means of Teachers Attitude Towards Using Visualization and Knowledge by Gender And Educational Level

Components	Variable		N	M	SD	t	df	p
Science and mathematics teachers' attitude towards teaching using visualization techniques	Gender	Female	51	3.67	.551	1.02	149	.312
		Male	100	3.57	.589			
	Educational level	Diploma	93	3.54	.560	-1.71	149	.090
		Degree	58	3.70	.594			
Confidence in applying visualization techniques	Gender	Female	51	3.46	.573	.004	149	.997
		Male	100	3.44	.558			
	Educational level	Diploma	93	3.37	.550	-1.98	149	.049
		Degree	58	3.55	.565			
Usefulness of science and mathematics visualization techniques	Gender	Female	51	3.65	.667	.696	149	.488
		Male	100	3.56	.680			
	Educational level	Diploma	93	3.51	.669	-1.87	149	.064
		Degree	58	3.72	.669			
Enjoyment in using science and mathematics visualization techniques	Gender	Female	51	3.93	.795	1.71	149	.089
		Male	100	3.70	.765			
	Educational level	Diploma	93	3.75	.791	-.622	149	.535
		Degree	58	3.83	.766			
Knowledge of implementing visualization techniques	Gender	Female	51	3.81	.442	.396	149	.693
		Male	100	3.78	.543			
	Educational level	Diploma	93	3.77	.531	-.874	149	.384
		Degree	58	3.85	.476			

c) ***Teachers' Knowledge, Attitude and Practice by Subject Taught***

Literature depicts that subject nature matters in an attempt to implement visualization techniques. Thus, an attempt was made to check if there is difference in teachers' knowledge, attitude and practice with respect to subjects they teach. For this purpose, one-way ANOVA test was used since the assumptions of independence, normality of the data and homogeneity of variances were met.

Table 6 (see on the next page) shows descriptive statistics and ANOVA results for science and mathematics teachers' attitude and knowledge towards implementing visualization techniques with respect to subjects they teach.

From the descriptive results in Table 6 it seems that biology and chemistry teachers have higher mean scores in the components of attitude and knowledge of implementing visualization techniques. But the ANOVA result indicates that there is no statistically significant difference between subjects they teach in terms of teachers' attitude, confidence, usefulness and enjoyment towards teaching using visualization techniques, and knowledge of implementing visualization techniques (F = .989, F =.669, F = 1.442, F = 1.274, and F = .459 respectively at p > 0.05). These indicate that the attitude, components of attitude and knowledge of science and mathematics teachers do not differ with respect to subjects.

Table 6
Comparison of Means of Attitude and Knowledge Towards Implementing Visualization Technique by Subjects teachers Teach

Components	Subject taught	N	M	SD	F	P
Science and mathematics teachers' attitude towards teaching using visualization techniques	Mathematics	49	3.51	.545	.989	.400
	Physics	27	3.56	.522		
	Chemistry	36	3.71	.553		
	Biology	39	3.64	.665		
Confidence in applying visualization techniques	Mathematics	49	3.43	.547	.669	.573
	Physics	27	3.34	.655		
	Chemistry	36	3.43	.465		
	Biology	39	3.53	.597		
Usefulness of science and mathematics visualization techniques	Mathematics	49	3.46	.639	1.422	.239
	Physics	27	3.53	.611		
	Chemistry	36	3.73	.635		
	Biology	39	3.67	.776		
Enjoyment in using science and mathematics visualization techniques	Mathematics	49	3.66	.668	1.274	.285
	Physics	27	3.83	.801		
	Chemistry	36	3.98	.775		
	Biology	39	3.72	.885		
Knowledge of implementing visualization techniques	Mathematics	49	3.76	.554	.459	.711
	Physics	27	3.76	.637		
	Chemistry	36	3.82	.454		
	Biology	39	3.87	.403		

With an attempt to check if there is any meaningful difference in the teachers' practices in implementing visualization techniques, ANOVA was calculated and the result did not show any statistically significant difference with respect to subjects the teachers teach (F = 1.005, F = .723, F = 1.343; F = .842; and F = .453 respectively at p > 0.05). These indicated that the science and mathematics teachers have the same practices of implementing visualization techniques in teaching; designing lessons using visualization techniques; teaching concepts using visualization techniques; exposing students to practice visualization of concepts; and assessing students on visualizing concepts in all subjects.

Discussions

Visualization techniques are important in promoting students' learning (Stieff, Bateman & Uttal, 2007), illustrating an idea that words cannot describe (Linn, 2003), simplifying the abstract nature of science and mathematics (Bishop, 1989), working with problems (Rösken & Rolka, 2006), enhancing efficacy (Bagni, 1998), and reducing students' anxiety (Hak, 2014). Therefore, the present study investigated the teachers' knowledge, attitude and practices in implementing visualization techniques in teaching-learning of science and mathematics and to check whether there is difference with respect to gender, educational level and subject they teach to elucidate recommendations.

Descriptively teachers' knowledge and practices in implementing visualization techniques were found to be below average. This was especially due to teachers' lack of knowledge in explaining concepts using non-examples and applying animation or simulation using computer or software. But teachers seem to have positive attitude towards visualization techniques. It was also revealed that science and mathematics teachers had similar knowledge, attitude and practices of implementing visualization techniques with respect to gender, educational qualification, and subject they teach except for confidence at which degree teachers are slightly significantly better than diploma teachers in teaching using visualization techniques. If training duration and level affects their confidence, it is worth studying further. Linn's (2003) showed that teachers need extensive background knowledge in order to interpret visualizations; Koeher and Mishra (2005) also indicated that teachers need to understand the different technologies available that support the content to be taught and the best pedagogical approaches to fit the purposes. In this regard, the respondent teachers had sufficient experience, but results did not show consonance of these. However, the result of this study is consistent with the study of Jasute (2013) indicating that most teachers have not assimilated technology usage. For teachers' attitude, the result is consistent with the findings of Balanskat, Blamire and Kefala (2006) and Mayer (2001) who indicated that teachers had a positive perception of visualization tools; but Becta (2004) indicated that lack of teachers' confidence is one of the barriers to the successful integration of visualization techniques in teaching and learning environments.

Teachers' practices in implementing visualization techniques are shown to be low, even though, visualization helps to enhance students' conceptual understanding (Serpil, Cihan, Sabri and Ahmet, 2006). The current study tells us weak implementation of the visualization techniques. The result of the study is consistent with the study of Jasute (2013) mentioned above. In order to implement visualization techniques in the classroom, teachers should prepare beforehand in their planning what type of visualization techniques they need to use for a specific topic, when to use that, at which level (introduction, presentation, conclusion and assessment level) is it appropriate and how to use it, including knowledge about it and whether students can practice it. In addition, teachers need to teach the lesson by integrating the visualization techniques with the content to simplify the abstract nature of the contents, connecting the lesson with real-life contexts, and using it for problem-solving. It is also worthy to help students to practice it and solve problems by using visualization techniques. Finally, teachers should use visualization to assess the students' learning progress.

Conclusion and recommendations

All researchers agree that visualization techniques are helpful in the teaching-learning of science and mathematics, but this is true only when teachers have necessary knowledge and positive attitude towards visualization techniques. Generally, this study revealed problems in science and mathematics teachers' knowledge and practices in implementing visualization techniques and particularly teachers lack of knowledge in explaining concepts using non-examples and applying animation or simulation using computer or software. But science and mathematics teachers have positive attitude towards visualization techniques. These indicated that an intervention should be taken in order to improve the knowledge and implementation practices of teachers for different appropriate visualization techniques.

Therefore, for proper implementation of visualization techniques it is recommended that appropriate tools should be provided to schools, teachers should be trained on how to implement them, the textbooks and teachers' handbook should be revised by incorporating appropriate visualization techniques. Finally, teachers also need to be supported during implementing visualization techniques in their mathematics and science lessons.

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