UNIVERSITY OF CAPE COAST

EFFECT OF VIDEO-BASED INSTRUCTION ON STUDENTS' RELATIONAL UNDERSTANDING AND ATTITUDES IN SOLID MENSURATION

OSMOND AMPONSAH ASIAMAH

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BY

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Thesis submitted to the Department of Mathematics and Information, Communication and Technology Education of the Faculty of Science and Technology Education, College of Education Studies, University of Cape Cost, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Mathematics Education

JUNE 2020

DECLARATION

Candidate’s Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this University or elsewhere.

Candidate’s Signature:……………………… Date:…………………….

Name: Osmond Amponsah Asiamah

Supervisors’ Declaration

We hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Cape Coast.

Principal Supervisor’s Signature………………….. Date:………………..

Name: Prof. Jonathan Arko Fletcher

Co-supervisor’s Signature………………………… Date:………………..

Name: Mr. Alexander Asare-Inkoom

ABSTRACT

This study explored the effectiveness of the use of video-based instruction on students' relational understanding, their attitudes toward it, and their tendency to collaborative, in learning solid mensuration, in the Birim Central Municipality of Ghana. A mixed methods concurrent triangulation research design, embedded with one-group pre-test and post-test quasi-experimental design was employed. The same treatment and methodologies were used on two intact classes ($n = 43$ and $n = 39$ respectively) of the two study schools. Questionnaire, lessons test scores, interview reports and written test scripts of the students were the data sources of the study. Descriptive, paired sample *t*-test and effect size statistics were used to analyse the quantitative data, whereas the interview data and test scripts were analysed qualitatively. The two separate data sets produced similar results, with the qualitative results confirming and strengthening the quantitative results. The use of the video-based instruction was found to be effective in developing students' spatial ability and conceptual knowledge of solid mensuration concepts. The results also showed that students had positive attitudes toward the use of video-based instruction. Other findings were that the students benefitted socially, psychologically and academically from the collaborative learning strategies that were implemented in the study. The findings support the *enactivism* pedagogy of teaching adopted as the theoretical framework for the study. The results also provide evidence and recommendations on the significance of video-based instruction in improving students' relational understanding and attitudes toward learning with video-based instruction, at the Senior High School level.

KEY WORDS

Attitudes

Collaborative Learning

Enactivism

Mixed Methods Design

Relational Understanding

Quasi-Experimental Design

Solid Mensuration

Video-Based Instruction

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DEDICATION

To my father's memory, beloved family and friends for always supporting, helping and standing by me.

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CHAPTER ONE

INTRODUCTION

This study investigated students' relational understanding of solid mensuration and their attitudes toward the subject domain. Video-based instruction was used in the teaching and learning of solid mensuration concepts in an interactive and collaborative learning environment. According to literature (Bragg & Outhred, 2004; Chappell & Thompson, 1999; Curry, Mitchelmore & Outhred, 2006; Grant & Kline, 2003; Martin & Strutchens, 2000), students have poor and superficial understanding of solid mensuration concepts; length, surface area and volume measurements. However, it is an important topic not only for mathematics, but also for some other fields of study and our everyday use. The study was underpinned by the enactivist theory of teaching and learning. Enactivist theory combines the ideas of constructivism and embodied cognition (Holton, 2010). It, therefore, blends the ideas of traditional and contemporary teaching and learning principles.

Background to the Study

Mathematics holds a key position in the school curriculum and in practically all countries it is a core component of the school programme of study (Keith, 2000). Again, Keith holds the view that mathematics is seen as a pivotal subject, both in its own right and because of its important connections with diverse fields like the natural sciences, engineering, medicine and the social sciences. Consequently, everyone needs to understand mathematics, regardless of their personal characteristics, backgrounds, or physical challenges. Students should therefore be supported to learn significant mathematics with depth and understanding (National Council of Teachers of Mathematics (NCTM), 2000).

Mathematics at the pre-tertiary level in Ghana.

The pre-tertiary mathematics curricula are based on the twin premises that all students can learn mathematics and that all need to learn mathematics. To achieve these requires a sound mathematics curriculum, as well as competent and knowledgeable teachers who can integrate instruction with assessment in classrooms with ready access to technology. It also requires promoting cooperative learning among students, the use of student-centred teaching approaches and a commitment to both equity and excellence (MoE, 2010).

However, the phenomenon of high-stakes examinations that characterises Ghana's educational and political climate keeps increasing the pressure on teachers to improve students test scores and grades while making sure that all students meet minimum requirement for admission into Senior High Schools and tertiary institutions. Teachers are therefore pressured to cover all tested standards without striving for in-depth student learning (Ottevanger, van den Akker & de Feiter, 2007). Thus, most classroom interactions are overwhelmingly teacher-centred (Agyei & Voogt, 2011; Ampiah, Akyeampong & Leliveld, 2004; Ottevanger et al., 2007) and examination driven. This traditional way of mathematics teaching emphasizes procedures, computation and algorithms. There is little attention to developing conceptual ideas, mathematical reasoning and problem solving activities (Haavold, 2011, p. 195). In such environment, students are rarely asked to explain their answers and communicate mathematical arguments to others, and the main activities in the classroom are direct instruction from the teacher and students working on problems on their own (Haavold, p. 194). Teachers have therefore relied on workbooks, drills memorization, practice and reinforcement to present mathematical concepts. However, teaching mathematics through these approaches has proven to be ineffective and outdated (Cain-Caston, 1996, p. 270).

This "old" style of teaching, strictly from the front of the class using a chalk/marker board is no longer capable of effectively reaching all students. This echoes the findings of researchers (e.g.; Agudelo-Valderrama, 1996; Anamuah-Mensah & Mereku, 2005; Eshun, 2004; Eshun-Famiyeh, 2005; Masingila, 1993) who claimed that a greater proportion of students find mathematics difficult and they are not able to apply what they have learnt to their real life situations because of the way the subject is taught. What is more, the teacher-centred instructional approaches have also been criticized for failing to prepare students to attain high achievement levels in mathematics (Hartsell, Herron, Fang & Rathod, 2009).

Role of technology in mathematics classrooms

Technology use in today's mathematics classroom is believed to be effective in teaching and learning, thereby having positive impact on students' success and attitudes towards lessons. In the NCTM (2008) position statement, it claimed that "technology is an essential tool for learning mathematics in the 21st century, and all schools must ensure that all their students have access to technology" (p. 1). Hence, "effective teachers optimize the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in mathematics" (NCTM, 2011, p. 1). The

Association of Mathematics Teacher Educators (AMTE) (2006) also identified that technology can be used to: (a) improve and enhance the teaching and learning of mathematics, (b) facilitate mathematical discovery, understanding, and connections that may be difficult or impossible without its use, (c) enable users to efficiently generate and manipulate a variety of representations of mathematical ideas and processes, (d) analyse or create images, visualizations, and simulations provide wide-ranging opportunities for mathematical exploration and sense making, (e) foster, and support students' construction of mathematical knowledge in a variety of ways (p. 1).

The use of ICT in mathematics classes allows students to discover principles and concepts, practise skills and procedures, look up information and process and analyse data (Anamuah-Mensah, Mereku & Asabere-Ameyaw, 2004; Anamuah-Mensah, Mereku & Ghartey-Ampiah, 2008). So and Kim (2009) called attention to the fact that technology can play a critical role in representing a certain subject matter to be more comprehensible and concrete, helping students correct their misconceptions on certain topics and improving learning outcomes (p. 103). Overall, "it offers significant opportunities for students to learn mathematics better" (Fletcher & Anderson, 2012; p. 76).

Available ICT tools for mathematics instructions

The NCTM (2011) categorised technological tools used in mathematics education into two main groups, namely; content-specific and content-neutral. Content-specific technologies include: Computer Algebra Systems (e.g., Maple, Math Lab, Mathematica, Derive, and TI-Inspire calculators), Dynamic Geometry Systems (e.g., Cabri, Geometer's Sketchpad and GeoGebra), interactive applets, handheld computation, data collection and analysis devices, and computer-based applications. These technologies support students in exploring and identifying mathematical concepts and relationships. Content-neutral technologies include: communication and collaboration tools and Web-based digital media, virtual manipulatives, multimedia (audio-visuals/videos), Interactive White Boards, internet, Java Applets etc.

Integration of ICT into Ghana's pre-tertiary education curriculum

Teachers are encouraged to use calculator and computer to help students acquire the habit of analytical thinking; learn from feedback; observe patterns; and apply knowledge in solving practical problems (Ministry of Education, 2010; MoE, 2012a; MoE 2012b). The mathematics curricula explicitly outline the teaching and learning methods and strategies to be used when teaching a particular topic (MoE, 2010; 2012a; 2012b). Yet, according to Ampadu (2012), "the transition from theory to practice continues to be one of the major issues challenging progress in most mathematics classrooms" (p. 84). Ottevanger et al. (2007) also observed that in Sub-Saharan Africa there are nice jargons in the curriculum, stressing on how instructions should be carried out, but this is not seen in the classroom. Thus, there is a huge gap between the intended curriculum and what is implemented in the classroom. Indeed, there still exists a gap between the use of technology-based instruction, as enumerated in the policy documents and mathematics curricula, and the use of technology in practice.

Undoubtedly, even with the abundance of technologies available at schools, many teachers do not have the knowledge necessary to effectively integrate these technologies into their lessons (Davis, 2002) and even if they have, the ultimate responsibility is left to the mathematics teachers to integrate technology into classrooms as the tool simply being present in the classroom is not enough (NCTM, 2000). In a similar vein, Agyei and Voogt (2011) affirmed that mathematics teachers in Ghana do not integrate technology in their teaching despite government efforts in the procurement of computers and establishment of computer laboratories in most Senior High Schools. They argued that the use of the teacher-centred approach and lack of in-service and pre-service teachers' knowledge of ways to integrate technology in teaching as the main barriers.

It is evident from the discussions that using technology in the mathematics classroom is not just an option anymore; but a necessity (Boggan, Harper and Bifuh-Ambe, 2009). Most importantly, today's students were born into a world with technology, so using technology-based instruction in mathematics should be natural for them. Therefore, to exclude these devices is to separate their classroom experiences from their real-life experiences.

My investigation into this problem of practice was necessitated by my curiosity and personal experiences to explore the effect of video-based instruction on students' learning of an aspect of mathematics — solid mensuration. My motivation for this study was to: (a) design a technology-based instructional module for teaching and learning solid mensuration; (b) explore ways of addressing if not all, some of the students' learning difficulties, mistakes and misconceptions on solid mensuration identified in the literature; and (c) address the almost lack of research evidence on the use of video-based instruction in mathematics education, particularly in Ghana.

Statement of the Problem

Learning geometry is not just learning the definitions or the attributes of geometrical concepts, but also to have the ability of analysing the properties of two dimensional (2D) and three dimensional (3D) geometric shapes and develop mathematical arguments about geometric relationships, to specify locations and spatial relationship, to apply transformations and to use symmetry, visualization, spatial reasoning, and geometric modelling to solve problems (NCTM, 2000). The emphasis placed on solid mensuration shows that students have to acquire deeper understanding of its concepts to enable them apply in both school and real-life contexts. However, literature point to the fact that students have difficulties in learning and understanding this aspect of mathematics. The following are the mostly reported students' difficulties in solid mensuration found in the literature: (a) inability to imagine and interpret drawn objects correctly, (b) confusion when visualizing and shifting from 2-dimensional to 3-dimensional views and vice versa, (c) inability to recall appropriate formulas during computations, and (d) confusing the concept of volume with the surface area and their formulas (Battista, 2003; Owens & Outhred, 2006; Voulgaris & Evangelidou, 2004).

Candidates' performance in solid mensuration at West African Secondary School Certificate Examination (WASSCE)

The WAEC Chief Examiners' reports on candidates' performance in the WASSCE Core Mathematics Paper 2 on questions centred on solid mensuration over the years (i.e., considering the years 2011 to 2015) are quite revealing as far as the statement of the problem for this study is concerned.

This section highlights some of the comments for both the school (May/June) and private (November/December) candidates' examinations.

***WASSCE May/June, 2011 Question 4 (b)*:** A cube of length 4 cm has the same volume as a cone with base diameter 7 cm. Find, correct to the **nearest** cm, the height of the cone. [Take $\pi = \frac{22}{7}$].

***Chief Examiners comments*:** In (b), "a lot of candidates could not quote the formula for the volume of a cone correctly..." (p. 278-279).

WASSCE November/December, 2011 Question 11.

The diagram in Figure 1 is a right pyramid with a triangular base PQR and height $|SN|$. If $|PQ| = 6\ cm$, $|PR| = |RQ| = 5\ cm$, $|PN| = 3.3\ cm$ and $\angle SPN = 52°$, calculate, correct to **two** significant figures, the

(a) vertical height $|SN|$ of the pyramid,

(b) area of the base of the pyramid,

(c) volume of the pyramid,

(d) angle between the slant face SPQ and the base PRQ of the pyramid.

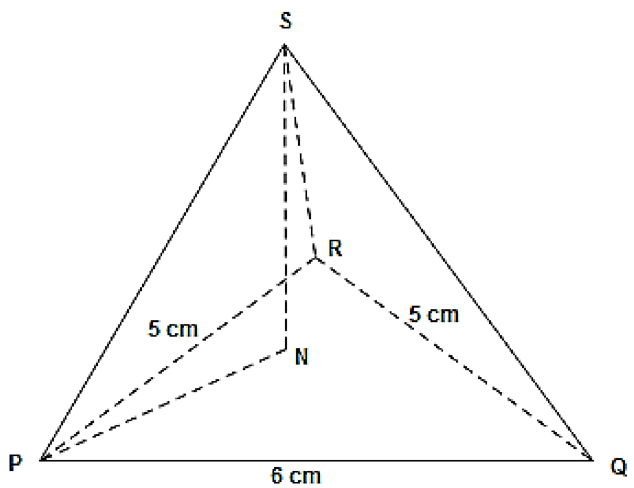


Figure 1. WASSCE November/December, 2011 Paper 2, Question 11.

***Chief Examiners comments*:** "This was attempted by just a few of the candidates. Parts (a) and (b) were answered correctly. However, parts (c) and (d) challenged the candidates greatly" (p. 236-237).

***WASSCE May/June, 2012 Question 9 (a)*:** A container in the form of a cube of side 24 cm is three-quarters full of water. How many litres of water does it hold?

***Chief Examiners comments*:** "Performance in (a) was good since most of the candidates who attempted it recognized that it was about the volume of a cuboid" (p. 296).

***WASSCE November/December, 2012 question 9 (b)*:** The Figure 2 shows a cone whose upper part has been cut off. The base radius is 6 cm and the upper radius is 3 cm. If the height of the remaining portion is 4 cm, calculate, correct to the **nearest** whole number the volume of the:

(i) original cone;

(ii) remaining portion. [Take $\pi = \frac{22}{7}$].

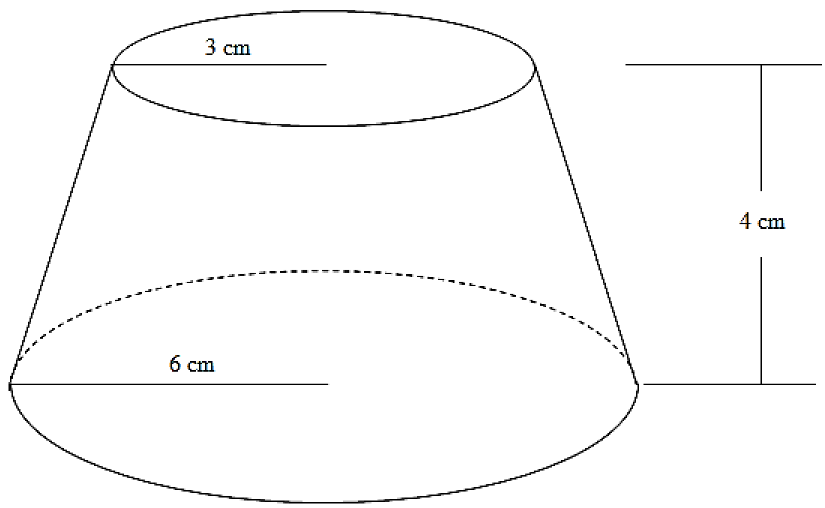


Figure 2. WASSCE November/December, 2012 Paper 2, Question 9 (b).

Chief Examiners comments**:** "All those who answered it performed below average. Candidates could not compare the height and radius of the two cones in order to obtain the height of the original cone, which is key to the problem …" (p. 430).

WASSCE November/December, 2013 Question 2**:** The diagram in Figure 3 shows a hut used in storing grains which is in the shape of a triangular prism mounted on a cuboid. If he dimensions are as shown in the diagram, calculate the: (a) volume of the hut,

(b) total external surface area of the hut.

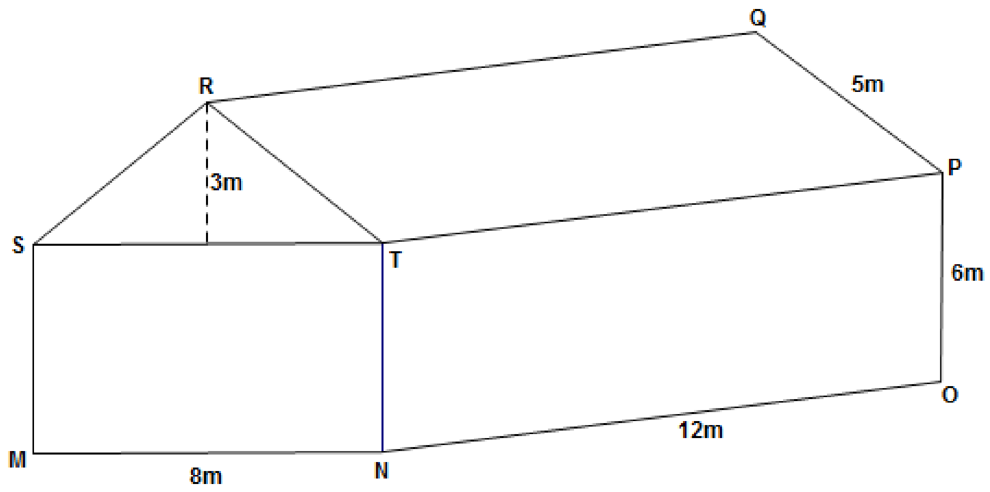


Figure 3. WASSCE November/December, 2013 Paper 2, Question 2.

Chief Examiners comments**:**

In part (a), most candidates were able to find the volume of the cuboid but failed to find the volume of the triangular prism due to their inability to use the correct formula. However, few candidates showed mastery in computing the volume of the hut by summing up the volumes of the cuboid and that of the triangular prism. The part (b) was a disaster; since most candidates could not visualize that the total surface of the hut was twice the sum of the distinct surface areas. Their overall performance was not encouraging (p. 292-293).

***WASSCE November/December, 2014 Question 5*:** The diagram in Figure 4 shows a right pyramid with a rectangular base $WXYZ$ and vertex O. If $|WX| = 8\ cm$, $|ZW| = 6\ cm$ and $|OX| = 13\ cm$, calculate the:

(a) height of the pyramid;

(b) value of $\angle OXZ$, correct to the **nearest** degree;

(c) volume of the pyramid.

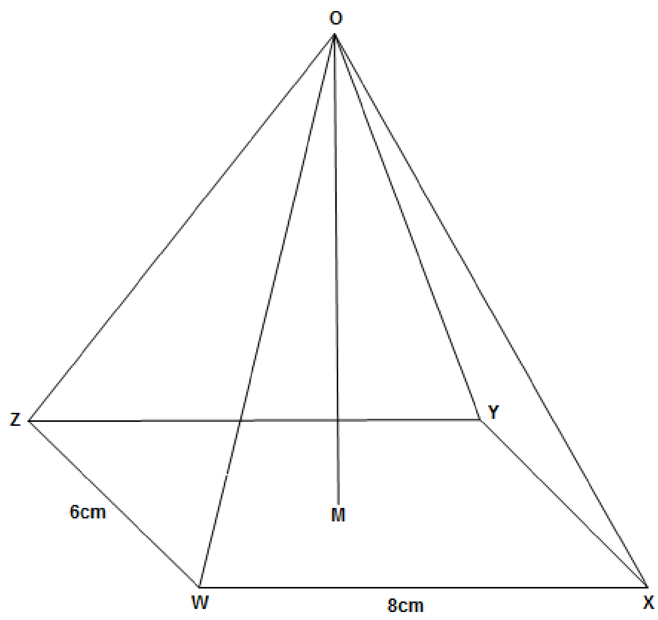


Figure 4. WASSCE November/December, 2014 Paper 2, Question 5.

***Chief Examiners Comments*:**

Few candidates who attempted the question answered correctly. However, some could not determine the height of the pyramid because they failed to recognize that $MX = \frac{1}{2}ZX$. Again, some quoted the formula for the volume of the pyramid as: $V = \frac{1}{2} base\ area \times height$ instead of $V = \frac{1}{3} base\ area \times height$ (p. 290-291).

WASSCE May/June, 2015 Question 12**:** A water reservoir in the form of a cone mounted on a hemisphere is built such that the plane face of the hemisphere fits exactly to the base of the cone and the height of the cone is 6 times the radius of its base.

(a) Illustrate this information in a diagram.

(b) If the volume of the reservoir is $333\frac{1}{3}\pi m^3$, calculate, correct to the nearest whole number, the:

(i) volume of the hemisphere;

(ii) total surface area of the reservoir. [Take $\pi = \frac{22}{7}$]

Chief Examiners comments**:** "The performance of those who attempted it was poor. Majority of the candidates were not able to represent the given information in a correct diagram. Others could not apply the formula correctly." (p. 480-481).

From the reports, apart from the May/June, 2012 question 9 (a) where candidates' performance was commended, they have generally not performed well on solid mensuration questions. Besides, in each of the reports there are suggested remedies to help improve candidates' performance in subsequent exams, surprising the problems re-emerge. Is it that teachers do not come in contact with these reports or even if they do, they are not implementing the suggested remedies? The use of video-based instruction technology for the study was in line with some of the suggested remedies in the reports (e.g., November/December, 2010, p. 238 and May/June, 2015, p. 470).

Regarding the gap in knowledge on the use of video-based instruction to teaching and learning of mathematics, there is somewhat limited body of research available. Moreover, when this present study began in 2016, no study had specifically investigated the effect of the use of video-based instruction on students learning and understanding of solid mensuration. Majority of the studies conducted in this area used virtual manipulatives. Many of these studies too have explored either the students' performance or the development of students' concept growth in a single domain of solid mensuration. Therefore, there is a dearth of research on students' learning and understanding of solid mensuration oriented tasks on; length, angle measure, lateral height, area of lateral face, surface area and volume measurements altogether.

Even though studies have shown that students taught solid mensuration concept(s) by integrating technology-based pedagogy have significantly outperformed those taught using the traditional teacher-centred approach, researchers have failed to reveal in their studies students' attitudes to learning solid mensuration using the particular instructional technology they employed. The critical questions that still remain unanswered, and which will influence the research questions for the study are: 'what effect has technology-based instruction on students' relational understanding of solid mensuration?'; 'what effect has technology-based instruction on students' attitudes to learning?' and 'do students tend to collaborate in technology-based instructional setting?'

Purpose of the Study

The purpose of this study was to investigate the effectiveness of video-based instruction to students' relational understanding, their attitudes to the use of video-based instruction in learning, and their tendency to collaborate in learning solid mensuration. A concurrent triangulation mixed methods design embedded with one-group pre-test and post-test quasi-experimental design was used, and it involved collecting both quantitative and qualitative data separately and then corroborating the quantitative results with in-depth qualitative data.

Research Questions

In pursuit of the purpose of the study stated, the research was guided by the following research questions:

1. What is the effect of video-based instruction on students' relational understanding of solid mensuration?
2. What is the effect of video-based instruction on students' attitudes toward learning solid mensuration?
3. What is the effect of video-based instruction on students' tendency to collaborate in learning solid mensuration?

Significance of the Study

Videos have been known to be more effective as both instructional and cognitive tool (Berk, 2009; Goldman, 2004; Johnson, 2013), however, there is lack of research evidence on its use in mathematics lessons, particularly in Ghana. It is expected that the results of this research will not only mark the beginning of research into video-based instruction in mathematics lessons; but will also create the awareness for educational practitioners and teachers on its potential in engaging learners attention and interest, and its ability to make lessons realistic and practical.

The findings will also draw the attention of mathematics teachers to be resourceful and innovative in enacting technology-based mathematics lessons. Ultimately, the product of this study, *Module for Teaching Solid Mensuration using Video-Based Instruction*, would add on to the existing mathematical modules, which may be used to complement the traditional teacher-centred approach often used in teaching solid mensuration concepts. Lastly, the findings on students' attitudes to learning using video-based instruction will widen the discussion for educators, teachers and parents on the need to help build students' confidence that everyone can "do" mathematics for students to appreciate the value of mathematics in their lives (Ministry of Education, Ontario, 2004).

Delimitations

The study of school geometry covers a wide area, however, for the sake of this study; emphases were laid on right solid shapes and measurements. The lessons on solid mensuration were delimited to the following content areas: construct solid shapes from their nets; identify and sketch solid shapes according to their names; find the surface area and volume of solid shapes, including composite, frustum and recast shapes. These areas are prescribed in the MoE (2010) teaching curriculum and the WAEC (2014-2020) examination curriculum, on Core Mathematics.

Also, the study was delimited to two third year intact classes, one from each of the two Senior High Schools involved in the study. This was to avoid interaction among the students from the two schools. The use of the intact class was to ensure that the whole class benefited from the study. The study was carried out in the Birim Central Municipality. The area was chosen because of its familiarity to me and easy accessibility of the population for the study. Finally, the study was conducted at the schools' computer laboratory, as they were equipped with the basic facilities which accommodated the video-based instruction.

Limitations

Although the research has achieved its aims, there were some limitations and shortcomings. First of all, the study was conducted on only two intact classes of 82 students, made up of 43 students of school M and 39 students of school N. The population of the experimental groups represent a small size of the population of the study. This might not represent the majority of the students from even the one municipality for which this study was conducted. Therefore, to generalise the results for larger groups, the study should have involved more intact classes from more schools. Second, after completing my interpretation of findings, I discovered that I did not include a question on *Real-Life Connections* of instruction in the interview guide. This inhibited my ability to conduct a thorough analysis on this particular aspect of the study. All the same, some of the interviews responses to other questions gave some information on it.

A further limitation of this study was my role as a designer, instructor and researcher in the study. It is worth acknowledging the element of selectivity in some of the decisions I took. One area of selectivity was the nine video-based lessons designed and enacted (see Table 6). The lessons objectives, sequencing of the topics and the number of lessons were based on my own examination of the teaching curriculum (MoE, 2011), examination curriculum (WAEC, 2014-2020) and literature I reviewed on students' weaknesses, misconceptions and errors in solid mensuration. So, after enacting the lessons and also from some of the interview reports, I realised the lessons should have been ten. This is because, the lesson nine was too loaded and some students complained they did not understand the frustum concepts.

Another area of selectivity was the analysis and interpretation of the data. For instance, the themes generated from the data were based on my own interpretation and understanding of the literature I reviewed for the study.

Lastly, students' prep periods for which the lessons were taught made some of the students to absent themselves. Due to this, not all the participants took part in all the nine written tests on the nine lessons enacted. Hence, each student's performance in solid mensuration was measured using his/her mean score (i.e., total score in all the number of written tests participated in against the number of test taken). This same situation of students' absentee influenced my decision to randomly select students from only those who participated in all the nine lessons for interview. Nevertheless, the qualitative data analysis gave enough evidence in support that the students' gained a relational understanding of solid mensuration concepts.

Definition of Terms

Geometry. It is a branch of mathematics which studies point, line, plane, planar figures, space, spatial figures and the relationships between these as well as the measures of geometric figures such as length, angle, area and volume (Baykul, 2002). In this report, the terms solid geometry, solid mensuration and mensuration II were used interchangeable to mean the same.

Relational Understanding. Arsal (2009) defined relational understanding as comprising both conceptual and procedural knowledge. It means "knowing both what to do and why" (Skemp 1978, p. 9).

Collaborative Learning is an educational approach to teaching and learning that involves groups of learners working together to solve a problem, complete a task, or create a product" (Chandra, 2015; p. 4). For the purpose of this study, collaborative learning and cooperative learning means the same.

Attitude is concerned with an individual's way of thinking, acting and behaving and are formed as a result of some kind of learning experiences students go through (Mensah, Okyere & Kuranchie, 2013).

Physical Manipulatives are concrete objects used to help students understand abstract concepts in the domain of mathematics (McNeil & Jarvin, 2007).

Virtual manipulative is "an interactive, Web-based visual representation of a dynamic object that presents opportunity for constructing mathematical knowledge" (Moyer, Bolyard & Spikell, 2002, p. 373).

Video-based instruction: The term is used in the sciences of learning and cognition to designate knowledge or skills acquired by being taught via video.

Organisation of the Study

The study has been organised into five chapters. After this introductory chapter, the second chapter discusses the theoretical framework and literature review that highlights research works and ideas by other authors. Chapter Three deals with the research design, population, sampling procedures, data collection instruments, pre-testing of instruments, validity and reliability of research instruments, enactment of video-based instructional lessons, data collection procedures, data processing and analysis, ethical considerations. The presentation of the results and the discussion of the findings are captured in Chapter Four. The final chapter, Chapter Five looks at the summary of the study, key findings from the results of the study, conclusions, recommendations relating to the results of the study and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

Introduction

The study investigated the effect of video-based instruction with physical manipulatives on students' relational understanding of solid mensuration in the Birim Central Municipality. The study also explored students' attitudes and their tendency to collaborate with the use of video-based instruction in learning solid mensuration. This chapter discusses the theoretical framework underpinning the study and its significance. A literature review of works by authors and researchers on relevant issues pertaining to the problem understudy are also discussed. Finally, the chapter concludes with a summary on the literature review.

Theoretical Framework: Enactivism

This study was underpinned by the theory of Enactivism, which combines the ideas of constructivism and embodied cognition (Holton, 2010). So, it blends the ideas of traditional and contemporary teaching and learning principles. Enactivism was defined by Davis, Sumara, and Kieren (1996) as an embodied experience with patterns that shape the individual learner's learning and the creation of new knowledge. It holds the notion that knowledge is not pre-existent, but enacted (Davis & Sumara, 1997) through interactions between differing elements (Niessen, 2007).

Enactivism as pedagogical theory of instruction

Enactivism has two major premises. Firstly, the mind, body and world are inseparable (Fenwick, 2000), since the outcome of a specific learning activity is determined by the environment of the activity (time, place, etc.) and by the characteristics of the participant (gender, cultural background, action, etc.) (Li, Clark & Winchester, 2010). Secondly, learning occurs through feedback within the system (Fenwick). Therefore, enactivism views that cognition is a complex co-evolving process of systems interacting and affecting each other and their environments (Davis, Sumara, & Luce-Kapler, 2000).

The enactivist framework agrees with Dewey's pragmatist philosophy of education, which proposes that teachers and students are to work together as investigators in the classroom to create new knowledge (Dewey, 1930/1984a). The teacher's role is not to "impose certain ideas or to form certain habits in the child, but...to select the influences which shall affect the child and to assist him in properly responding to these influences" (Dewey 1929, p. 9). Consequently, he advocated for a teaching approach in which teachers and students both participate in educational experiences, where the teacher is seen as a natural leader in shared activity since he/she has greater maturity and wider knowledge (Dewey, 1930/1984b, p. 322). This paints a picture that "the teacher does not only acts as a facilitator in the teaching and learning process, but also as a partner who is actively involved in the creation and acquisition of new knowledge in the classroom" (Ampadu, 2012, p. 92).

Enactivism view on teaching and learning is also consistent with elements of Piaget's and Vygotsky's constructivist psychology and is based on the belief that "cognition and environment are inseparable and 'systems' enact with each other from which they learn" (Li, 2008, p. 3). The key component of enactivism is that learners and teachers or educators are co-authors and the classroom discourse is a two way affair and considers the individual as not simply an observer of the world, but as embedded in the world (Davis et al., 2000; Li, Clark, & Winchester, 2010). Thus, "learning affects the entire psyche of the individual …" (Ampadu & Adofo, 2014, p. 113). In enactivism, knowledge is viewed not as something separate from the learner but it is part of a complex system which includes the learner and all that the learner is associated with (Davis, Sumara & Kieren, 1996). So, everything that takes place within the classroom has an impact on students learning during instruction (Davis et al.). In the study, the researcher (i.e., teacher) and the students worked actively together and therefore became the complex system.

Enactivist view on instruction with technology

Within the enactivist paradigm, the use of computer tools is part of human living experience since 'such technologies are entwined in the practices used by humans to represent and negotiate cultural experience' (Davis et al., 2000, p. 170). Technological tools, as material devices and symbolic systems are considered to be mediators of human activity. They constitute an important part of learning because their use shapes the processes of knowledge construction and of conceptualization (Rabardel, 1999). In the classrooms, students can construct meanings through the use of computer tools, in the process of social interaction and with the guide of the teacher (Mariotti, 2001). Therefore, using videos for instructions in this study was in line with enactivist support for technology integration in mathematics classrooms.

Enactivism supports collaborative learning

Enactivist assert that learning is both an active and a participatory process. Maturana and Varela (1987) posited that "all doing is knowing, and all knowing is doing" (p. 27). According to Li (2012), a key element of enactivism is its focus on ‘‘knowing’’ instead of “knowledge”. This strong emphasis on “doing and knowing” is also a core characteristic of collaborative learning.

In enactivism pedagogy, teachers are not the source of knowledge in the classroom, but co-authors of knowledge with students by guiding their attention towards the intended goals (Li, Clark & Winchester, 2010). The teacher does not seek to facilitate nor direct the pupils in what to do and think, but promotes participation and genuine interaction to encourage learning (Proulx, 2009, p. 275). This “calls for a teacher that puts oneself into the action and acts vigorously in this learning space to trigger and provoke something in learners” (Proulx, 2009, p. 273).

Mathews (1997) argued that teacher’s active participation in the teaching and learning process is paramount, as there are still some mathematical concepts that the student cannot learn alone and the assistance of a teacher to trigger the students’ learning is necessary. Ampadu (2012) also found out that “ the majority of students still rely on the teacher as their main source of knowledge acquisition and see the construction of their own knowledge as ‘impossible’ without help or guidance from their teacher” (p. 275). As a result, “students have the impression that their success in mathematics depends on their ability to follow their teacher’s instructions and approaches of solving problems as they are custodians of knowledge” (p. 277).

The pedagogical principles of enactivism are reflected in the current pre-tertiary mathematics curricula. The curricula require teachers and students to actively participate in lessons. Teachers are encouraged to show, demonstrate and explain things to students. They are to avoid rote learning and drill-oriented methods and rather emphasise participatory teaching and learning. The curricula therefore only limit the teacher's effect on the teaching and learning process, which suggests that the teacher ought to be an active participant rather than a mere facilitator in the classroom.

On enactivism supporting collaborative or cooperative learning, Gillies (2003) reasoned that structured cooperative learning can lead to better learning outcomes and it is only when the teacher structures these groups in such a way as to ensure students understand how they must work that the desired results can be achieved. Next, Lee and Schäfer (2011) put forward that, enactivism encourages learning and the construction of knowledge through a collaborative process, and any learning situation must encompass the teacher, the student, the content and the context in order for some form of interaction to take place (p. 1). For that matter, in this study the researcher and students worked collaboratively and in an interactive ICT environment, which provided the platform to apply enactivism pedagogy.

Solid Geometry in Ghana's Pre-Tertiary Mathematics Curricula

Geometry is a branch of mathematics which studies point, line, plane, planar figures, space, spatial figures and the relationships between these as well as the measures of geometric figures such as length, angle, area and volume (Baykul, 2002). Mensuration consists of plane and solid mensuration. Plane mensuration deals with the measurements of lines, angles, perimeters and surface areas of plane (two dimensional) figures like triangles, polygons, circle among others, whiles solid mensuration deals with the measurement of volume of solid figures (three dimensional), examples prisms, pyramids, cylinder, cone, sphere , etc.. The aspects of solid geometry in the pre-tertiary curricula (MoESS, 2006; MoE, 2010; MoE, 2012a & 2012b) are summarised in Table 1.

Table 1: Solid Geometry in the Pre-tertiary Curricula

Year	Unit & Topic	Content
KG. 1	3. Drawing Shapes	Tracing and Drawing shapes from Real objects
KG. 2	6. Shapes	Drawing plane shapes from real objects
P. 1	6. Solid Shapes	Sorting objects by Shapes, Faces and Edges
P. 5	5. Measurement of Capacity	Measuring and Recording Capacities of containers
		Find Sum/Difference in the Capacities of two or more containers
	8. Shape and Space II	Number of: Faces, Vertices and Edges of Solid shapes
		Real objects with Edges meeting at Right angles
	9. Area and Volume	Areas of Plane Shapes
		Volume: Number of cubes used in building a cuboid
P. 6	6. Measurement of Capacity	Addition and Subtraction of Capacities
	8. Shape and Space	Classify Solid Shapes by the Number of Faces, Vertices and Edges
		Prisms (solid shapes with uniform cross section)
		Pyramids (solid shapes with non- uniform cross sections)
		Nets of Common Solids
	12. Measurement of Volume	Volume of Cuboids and Cubes
J.H.S. 1	4. Shape and Space	Classification of Solid Shapes
		Forming Solid Shapes from their Nets
		Relation Connecting Faces (F), Edges (E) and Vertices (V) of Solid Shapes: ($F + V = E + 2$)
	10. Capacity	Addition and Subtraction of Capacities
J.H.S. 2	6. Shape and Space	Common Solids and their Nets
	13. Area and Volume	Volume of Solid Shapes
		Word Problems involving Area and Volume
S.H.S. 3	3. Mensuration II	Nets of Prisms
		Surface Areas of: Prisms, Pyramids, Cylinder, Cone & Sphere
		Volume of: Prisms, Pyramids, Cylinder, Cone & Sphere
		Volume of Similar & Compound Shapes

A critical look at Table 1 indicates that solid mensuration concepts are reviewed at each level of the educational ladder and to the extent that in S.H.S. 3, students are supposed to be retaught the whole body of knowledge in solid mensuration under *Mensuration II*. After examining the content of *Mensuration II* in the curricula and past WASSCE Core Mathematics questions to date, it was worth noting that, to facilitate the teaching and learning of this topic, students should have prior knowledge of: *Change of Subject of an Equation*, *Plane Geometry I*, *Trigonometry I*, *Enlargement* (*Areas* and *Volumes of Similar Figures*) and *Mensuration I*.

Although the concepts in solid mensuration are repeated in the mathematics curricula, literature show that it is one of the topics students have difficulty in understanding and therefore they under perform in examination. Yet, the topic plays an essential role in all scientific disciplines, from physics to astronomy and chemistry, from engineering to figurative arts, as well as architecture and in everyday life. So, it seems very important to regard the study of solid geometry at school and the development of spatial sense as crucial for shaping the mathematical competence of students and for decision making. It was in the light of this situation that this study focused on the teaching and learning of solid mensuration and with the aim of improving students understanding and attitudes toward it.

Students' Misconceptions in Learning Solid Mensuration

Students' skills in visualizing and reasoning about spatial relationships are fundamental in geometry, but a lot of students treat 3D objects as 2D when in textbooks or computer screen, thus losing information (NCTM, 2000, p.

237; Aszalos & Bako, 2004). The discussion that follows highlights some of the students' misconceptions and difficulties when learning solid mensuration.

Citing Bayart et al. (2000) as reported by Bako (2003), in a survey students were to use the diagram in Figure 5 to answer the following questions. If ABCDEFGH is a cube and M, N, P are point of edges CG, BC, and HG, respectively then: (1) point P is on line AM, or not; (2) point P is on line MN, or not; (3) line AM and NM are the same lines, or not and then point P isn't on neither line.

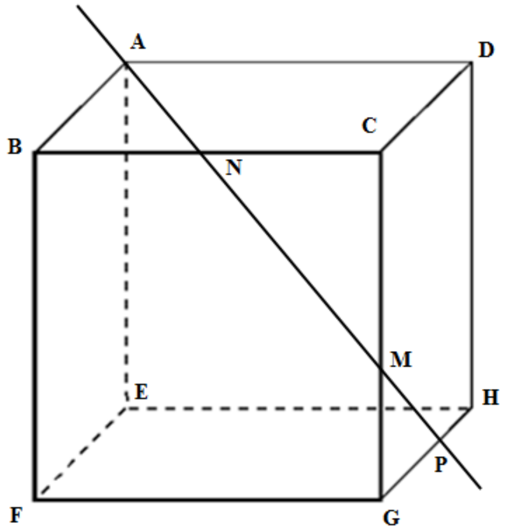


Figure 5. The diagram used in the survey conducted by the IREM of Strasbourg.

However, most of the students answered that the points A, N, M, and P are collinear. These students treated the diagram as a 2D figure.

Patkin (2015) reported that pupils at elementary and even junior high school, when they see a ball in reality, it will look like a circle in a drawing since it is hard to describe 3D figures in a drawing which has a 2D figure. Another example is that, a student may be given a cube, but he/she calls it a square; which demonstrates that the student does not understand the difference between 2D and 3D objects (Denenberg, 2011). Maida (2005) reported that through teaching pre-service teachers, observation was made that they had difficulty making connections between a flat cut-out and its respective folded-up solid. Hence, Maida recognized the need for strengthening skills of visualizing 3D solids from various 2D nets.

Owens and Outhred (2006) also observed that perpendicularity and parallelism have an impact on making and interpreting drawings and on concept formation. However, when solving problems, some students thought all intersecting lines were at right angles or did not recognise them in rectangles and even better students did not recognise right angles without horizontal and vertical sides (Owens & Outhred, p. 94). Likewise, students may not be aware of the right angles in the drawing of a 3D figure, which appear acute or obtuse in the drawing (Dreyfus & Hadas, 1991). Students also have difficulties in memorizing, recalling and manipulating solid mensuration formulas. For instance, Denenberg (2011) contended that too often when students learn about surface and volume, the activity becomes a "plug and chug" event where they simply try to find the right numbers to plug into a given formula and these calculations are meaningless and irrelevant to them.

Similary, Obara (2009) engaged pre-service secondary school teachers to come up with strategies for finding the total surface area of a given square pyramid model of base side length *s*, and height h. One group of students simply googled the formula for finding the total surface area of a square pyramid and found it to be $A = s\left(s + \sqrt{s^2 + 4h^2}\right)$. Though, the students were convinced that it would work, yet they could not explain and resolve why the formula was in that form when asked. The students were even more confused when asked to explain $\sqrt{s^2 + 4h^2}$ in the formula. Özerem (2012) in a study on 7th grade college students' misconceptions in geometry lessons also revealed that the students couldn't remember the formulas after the exams because they memorized them for the exams in short term memory. Thus, they could not create a positive attitude towards geometry and they were unable to associate it with their real lives (p. 31).

The minimal use of visualization tools in mathematics classroom (Sivasubramaniam, 2004), due to teachers' limited skills in using these tools (Handal, Herrington & Chinnappan, 2004) and teaching techniques (Özerem, 2012) also affect students understanding of solid mensuration concepts. According to Hwang, Huang & Dong (2009), in traditional classrooms, geometry learning is usually conducted through the description of text, 2D graphs and mathematical formulas on whiteboards or paper. They further emphasised that in measuring the area and volume of 2D or 3D objects, the use of traditional teaching methods often focus too heavily on the application of mathematical formulas and lack opportunities for students to manipulate and visualize the objects under study. Consequently, "many students can memorize the formulas and even appear to succeed in their course work without fully understanding the physical meaning of the math formulas or geometry concepts" (Tan, 1994 as cited in Hwang et al.; 229).

Studies on Solid Mensuration Instruction with Technology

Studies on solid mensuration instruction with technology have proven success in students' visualisation and spatial ability in transitioning between 2D and 3D shapes and vice versa. They have also shown positive effects on students' learning and performance. Baki, Kosa and Guven (2011) conducted a study to compare the effectiveness of Dynamic Geometry Software (D.G.S.) and physical manipulatives on the spatial visualisation skills of first-year pre-service mathematics teachers. A pre-test and post-test quasi-experimental design with three treatment groups was used. The Purdue Spatial Visualisation Test was used for the pre-test and post-test. The first group ($n = 34$) used D.G.S. Cabri 3D and the second group ($n = 32$) used physical manipulatives. The last group, the control group ($n = 30$) received traditional instruction. The results of the study showed that instruction with physical manipulatives and D.G.S. were more effective in developing the students' spatial visualisation skills than traditional instruction.

McClintock, Jiang and July (2002) studied on: *Students' Development of Three-Dimensional Visualization in the Geometer's Sketchpad Environment*. They investigated the effects of the Geometer's Sketchpad (G.S.P.) on 24 middle and high school students' three-dimensional visualization. They monitored the students' van Hiele levels of geometric thinking as they constructed dynamic GSP representations of geometric solids to conduct geometric investigations. They found out that "GSP and the associated activities had a distinct positive effect on the subjects when they were developing three-dimensional visualization and pursuing conceptual understanding of geometry content" (p. 754).

The study by Dimakos and Zaranis (2010) in Greece, investigated the question: *Does the use of a Geometer's Sketchpad help secondary students to improve their geometry performance?* The experimental group of 40 students spent at least one hour per week doing computer explorations for six weeks, while the 39 students in the control group were not exposed to the computer explorations. Students in both groups were pre-tested and post-tested for their geometry performance. The results of the study proved that the use of technology is needed for students to make significant progress in geometry.

In Ghana, Fletcher and Anderson (2012) also used the Geometer's Sketchpad to demonstrate that using the software for instruction in mensuration has a positive effect on students' learning and performance. They conducted the study in two S.H.S. using the quasi-experimental pre-test and post-test of non-randomization research design with a class of 40 students from each school to form the control and experimental groups respectively. The main advantage of the software compared to teaching with static diagrams drawn on chalk board was that it enabled the students to clearly see the diagrams on the computer screen, showing their geometric properties through animation. Thus, the technology enhanced students' visualization, mental images of 3D figures and interest in the lessons. They concluded that computers aid the learning of mensuration and recommended that teachers should be trained in using computers in mathematics education.

Gittinger (2012) explored using the GeoGebra to find the volume of given containers and surface area of 3D shapes (pyramids) from their nets, and used the GeoGebra solution checker to confirm their answers. The GeoGebra helped the students in developing both procedural and conceptual understanding through experiences with multiple models for representing concepts and encountering concepts in a wide variety of problem situations that serve to provide context for them.

Hwang et al. (2009) investigated students' perceived acceptance of Virtual Manipulatives and Whiteboard (V.M.W.) system and its influences on geometry concept learning. In all, 23 elementary students in 6th grade participated in the research over one-and-half months period. The students followed their teacher's instructions to solve eight geometry problems followed by collaborative discussion after solving problem. The Technology Acceptance Model-based Likert scale questionnaire results showed that the students perceived the V.M.W. system to be useful and easy to use. The content analysis of students' solutions when solving geometry problems in VMW system proved that more than half of the subjects relied on partition and stacking methods to find solutions to problems.

Gambari, Ezenwa and Anyanwu (2014) examined the effects of two modes of computer-assisted instructional package (Animation with Text (AT) and Animation with Narration (AN)) on solid geometry achievement among Senior Secondary School students in Minna, Niger State of Nigeria. The study adopted a pre-test and post-test experimental design with 3 x 2 factorial design. The two modes of Computer-Assisted Instructional package were employed to the treatment groups and the use of the Conventional (Lecture) method on the control group. Their findings were in favour of the use of CAI (AN). Based on that, they recommended that mathematics teachers should be encouraged to use CAI (AN) for meaningful and effective teaching and learning of mathematics.

Lastly, Gambari, Falode and Adegbenro (2014) also investigated the effectiveness of computer animation and geometry instructional model on mathematics achievement and retention on Junior Secondary School students in Minna, Niger State, Nigeria. They used the pre-test post-test experimental and control group research design on 60 students. The results of their study showed that the students taught geometry using computer animation performed significantly better in post-test and retention test than their counterparts taught geometry using instructional model and conventional method respectively. They concluded that geometry concepts could be taught and learnt meaningfully through the use of computer animations.

The studies with virtual manipulatives on the teaching and learning of solid geometry discussed so far have shown students success in visualisation and spatial ability in 2D and 3D medium. They have also shown improvements in students learning and performance. However, students' relational understanding in deriving and manipulating formulas when solving problems and their attitudes toward the use of the particular technology on their concept development remain rather unexplained. This study was therefore intended to factor out these issues. The study further examined the effect of video-based instruction on students' tendency to collaborative learning solid mensuration.

Audio-Visuals as Cognitive Tools for Instruction

The use of audio-visual aids in education has been found to be an effective way of communicating ideas and concepts to students (see for example Le Doux, 1996; Ouellette, 2004). Audio-Visual aids refer to those teaching materials some real, some graphic, not solely dependent upon words as a predominant source of meaning for the observer. Such aids include field and classroom study of real things, television programs, video tapes (recording and motion pictures), film slides (standard and miniature, both photographic and handmade), sound and silent film strips, projected study prints and other illustrations (opaque projections), objects for a micro projector (both slides as well as animate or inanimate specimens), photographic enlargements, text and pamphlet illustrations, magnetic tape, disk recordings, computer programs and graphic portrayals (maps, globes, graphs, charts, posters, diagrams and cartoons).

Audio-Visual aids are most effective tools for developing flawless communication and interaction between student and content, student and teacher; help to save the time of teacher and also help in developing and arousing curiosity, creativity and motivation (Akram, Sufiana & Malik, 2012). In this study, YouTube videos and physical manipulatives were integrated in the solid mensuration lessons as cognitive tools. However, the videos were predominately used. “A cognitive tool is an instrument that is a part of the learning environment that supports or performs an identifiable cognitive process that is part of the complete learning experience by the learner” (Van Joolingen, 1999; p. 389).

Garofalo, Drier, Harper, Timmerman and Shockey (2000) gave five guidelines for appropriate use of technology in mathematics lessons, which illustrate how the video-based instruction was integrated during the instructional session of the study. They are: (a) introduce technology in context; (b) address worthwhile mathematics with appropriate pedagogy; (c) take advantage of technology; (d) connect mathematics topics; and (e) incorporate multiple representations (p. 67). In this study, video-based instruction referred to teaching and learning with videos that appeal to the two most used senses; hearing and visual. One of the critical attribute of video is the use of both auditory and visual cues. The videos and physical manipulatives were integrated in the lessons.

YouTube videos

Marshall (2002) cited the conclusions of Wiman and Mierhenry (1969) who found that "…people will generally remember: 10% of what they read, 20% of what they hear, 30% of what they see and 50% of what they see and hear." Video is defined as the selection and sequence of messages in an audio-visual context (Canning-Wilson, 2000). According to Duffy (2008), "Video can be a powerful educational and motivational tool… Effective instructional video is not television-to-student instruction but rather teacher-to-student instruction, with video as a vehicle for discovery" (p. 124). Duffy defined YouTube as "a popular video sharing website where users can upload, view, and share video clips. YouTube is increasingly being used by educators as a pedagogic resource…" (p. 124).

Berk, 2009 on *Multimedia Teaching with Video Clips* identified 20 potential outcomes on the learning value of videos in the classroom, some of which are: grab students' attention; focus students' concentration; generate interest in class; create a sense of anticipation; energize or relax students for learning exercise; draw on students' imagination; improve attitudes toward content and learning (p. 2). Another advantage of using videos is pace, as they can be paused, rewound and fast forwarded when necessary. Its flexibility allows for both teachers and students to access their learning when they want to and work it around their busy schedules, because the videos are internet based and thus always available. The communication aspect of the YouTube videos is significant as it allows for the teachers and students to interact through discussion and activities (Johnson, 2013).

Zahn, Krauskopf and Hesse (2012) posited that for video to be effective for learning, its usage in class must extend beyond classic teacher-centred presentation approaches. It should foster student activities instead, such as having creative learning in task contexts that incorporate collaborative knowledge construction in small groups (Goldman, 2004). This view is in line with the enactivist theoretical position adopted for the study. It advocates for active teacher-student centred approach in a collaborative learning atmosphere during instruction. More so, the solid mensuration concepts and knowledge were embedded in the videos.

Physical manipulatives

McNeil and Jarvin (2007) defined manipulatives as concrete objects used to help students understand abstract concepts in the domain of mathematics. They are physical objects that are used as teaching tools to engage students in the hands-on learning of mathematics (Smith, 2009). When students manipulate objects, they are taking the first steps toward understanding mathematics processes and procedures. "The effective use of manipulatives can help students connect ideas and integrate their knowledge so that they gain a deep understanding of mathematical concepts" (A. Daigger & Company, n.d.).

Burns (2007) pointed out that manipulative materials help students make sense of abstract ideas, provide students ways to test and verify ideas, are useful tools for solving problems, and make mathematics learning more engaging and interesting by lifting mathematics off textbook and workbook pages. Manipulatives provide an additional resource in learning mathematics; they help children connect with real-world knowledge and they help increase memory and understanding (McNeil & Jarvin, 2007). Accordingly, "students are learning mathematics in an enjoyable way, making connections between the concrete and the abstract" (Furner, Yahya & Duffy, 2005, p.17). Another benefit is that teachers can use it to positively affect student learning of mathematics at all levels and of all abilities (Boggan, Harper & Whitmire, 2010).

Bruner's (1966) Enactive—Iconic—Symbolic progression in learning provides a basis for an effective framework for teaching with manipulatives. Under this framework, teachers begin with concrete manipulative experiences, transition students to using visual representations (drawings), and finally transition to using abstract (symbolic) mathematical notation. Research has also indicated that students who lack prior concrete experiences have difficulty in visualizing cross-sections of solids (Boakes, 2009). Students who cannot construe information about 3D solids drawn on paper or static board equally encounter difficulties in interpreting geometry problems when it comes to switching from 2D to 3D and vice versa. These limited experiences can affect students' spatial thinking skills and impede their progress in learning further geometry (Georgeson, 2011; Golan & Jackson, 2009; Gueven & Temel (2008).

Consequently, I used the videos and physical manipulatives to bridge the gap between real-life solid geometry and the formal classroom solid geometry concepts by switching students' reasoning from concrete through to abstract. The videos and physical manipulatives were integrated in the lessons. Thus, facilitating students' spatial abilities (i.e., spatial visualization and spatial orientation) when dealing with 2D and 3D objects.

Research on teaching and learning with audio-visual aids

Researchers have studied the use of audio-visual materials in teaching and learning in several different subject areas. Ode (2014), investigated the impact of audio-visual resources on teaching and learning. The findings revealed that the use of audio-visual resources had significant positive impact on the teaching and learning in the selected schools. The findings further revealed that the audio-visual resources: (a) stimulate interest and improve learning; (b) provide sources of information on every kind of learning thereby removing abstraction in teaching and learning; (c) promote better understanding and so create emotional balance which gives room to personality development; and (d) make individualized the individualize learning possible through programmed instruction.

The study by Quarcoo-Nelson, Buabeng and Osafo (2011) investigated the impact of audio-visual-aided instruction on S.H.S. students' achievement in physics at Cape Coast, Ghana. The results showed that students taught with audio-visual aided instruction performed better than those taught with traditional method. The researchers contended that the higher performance by the students may be as a result of the audio-visual aids to provide more concrete representations of ideas and concepts which were normally taught in abstract form in the regular physics classes. In another research, Igbojinwaekwu (n.d.) investigated the impact of videotaped instruction on learning of Senior School Mathematics. Students in the experimental group were exposed to Videotaped instruction, while students in control group had lesson through Conventional Lecture Method. It was found that experimental group had significant higher mean academic achievement than the control group.

Other studies have also shown that students who use "manipulatives in specific mathematical subjects are more likely to achieve success than students who don't have the opportunity to work with manipulatives" (A. Daigger & Company, n.d., p. 4). For instance, the study by Allen (2007) showed that students who used manipulative improved their level of achievement, increased their understanding, and promoted a positive attitude to a mathematical concept that they previously struggled with. The study by Akram, Sufiana and Malik (2012) also found out that the use of audio-visual aids in teaching of biology was very effective as it increased the level of interest and enhanced motivation for learning in students.

Relational Understanding

Two profile dimensions (i.e., Knowledge and Understanding, and Application of Knowledge) have been specified for teaching, learning and testing in Core Mathematics (MoE, 2010). For that matter, students must learn and acquire as much knowledge and understanding of mathematics as possible to develop mathematical skills, insights and attitudes, and adhere to values that will contribute successfully to their chosen careers and daily lives (MoE, 2010). Thus, students' relational understanding in solid mensuration was crucially important in this study. In this regard, two important questions needed to be answered:

1. What is relational understanding?
2. Why is learning with relational understanding important?

Meaning of relational understanding: Skemp (1978) compared two kinds of understanding: instrumental and relational. Instrumental understanding is considered as “rules without reasons” or “knowing what to do”, while relational understanding is “knowing both what to do and why” (p. 9). Instrumental understanding calls for rote learning or memorising which problems a method works for and which not, and also learning a different method for each new class of problems. It shows that ideas (e.g., concepts, procedures and formulas) are learned, but in isolation (or nearly so) to other ideas. In contrast, relational understanding means that each new concept or procedure is not only learned, but is also connected to many existing ideas, so there is a rich set of connections. It requires explaining why the rules or procedures work.

Skemp (1978) viewed instrumental understanding as beneficial for a short-term case within a limited context, whereas relational understanding is better for long-term learning in a broader context. In effect, he placed instrumental and relational understanding as two extremes, but rather than being divided, the former is actually a subset of the latter. Sapire-writer et al. (2008) and Arsal (2009) also viewed relational understanding as comprising both conceptual and procedural knowledge. Sapire-writer et al. asserted that “Conceptual knowledge of mathematics consists of logical relationships constructed internally and existing in the mind as a part of the greater network of ideas” (p. 30), while “Procedural knowledge of mathematics is knowledge of the rules and procedures that one uses in carrying out routine mathematical tasks. It includes the symbolism that is used to represent mathematics” (p. 35). To this, Arsal emphasised that mathematics teaching should include these three purposes: (a) students should have conceptual knowledge; (b) procedural knowledge and (c) they should understand the relationships between conceptual and procedural knowledge.

Kinach (2002) also contended that “to the teacher who embraces a relational view of mathematics, student achievement is much broader than remembering. Problem posing, critical and contextual thinking, the ability to justify and represent one’s thinking mathematically are all part of what mathematics achievement means” (p. 54). For this study relational understanding was considered as student’s ability in linking both procedural and conceptual knowledge (Arsal, 2009) in learning and understanding solid mensuration concepts.

Importance of learning with relational understanding: Skemp (1978) outlined four advantages in having relational understanding of mathematics concepts: (1) it is more adaptable to new tasks; (2) it is easier to remember; (3) relational knowledge can be effective as a goal in itself; and (4) relational schemas are organic in quality. Sapire-writer et al. (2008) (adapted from Van de Walle, 2004) also remarked that relational understanding: is intrinsically rewarding; enhances memory; is less to remember; helps with learning new concepts and procedures; improves problem-solving abilities; is self-generative and improves attitudes and beliefs. The rationale for the core mathematics curriculum is to “enable all Ghanaian young persons to acquire the mathematical skills, insights, attitudes and values that they will need to be successful in their chosen careers and daily lives” (MoE, 2010, p. ii). To achieve this, students need to possess relational understanding of mathematical concepts.

Attitude and Its Influence on Learning

Attitude as a concept is concerned with an individual’s way of thinking, acting and behaving and are formed as a result of some kind of learning experiences students go through (Mensah, Okyere & Kuranchie, 2013). Myers (2013) also stated that “attitudes are feelings, often influenced by our beliefs that predispose our reactions to objects, people, and events” (p. 574). Research suggests that the cognitive, affective and behavioural are three different components of attitude (Hogg & Vaughan, 2011; Maio & Haddock, 2010). Mensah et al. (2013) highlighted that the cognitive component is what the individual thinks or believes about the attitude object, while the affective is the feelings or emotions of the individual associated with the attitude object. Then, the behavioural component is the tendency to respond in a certain way to the attitude object. Hence the three components of attitude are interrelated and interconnected.

Within the domain of mathematics, Eshun (2004) was of the view that “people develop attitudes towards mathematics just as they tend to develop attitudes towards people and … politics, religion, institutions and school subjects” (p. 2). He defined attitude towards mathematics as a disposition towards an aspect of mathematics that has been acquired by an individual through his or her beliefs and experiences but which could be changed. Eshun further reasoned that positive attitudes towards mathematics are desirable since they may influence one’s readiness and willingness to learn and benefit from mathematics instruction (p. 2).

Eshun (2004) also called on mathematics teachers to rely on students’ positive attitude towards mathematics as an indication that they can be effectively assisted to learn mathematics when provided with the environment that motivates them by building their confidence in doing mathematics and lessen their anxiety. Yara (2009) asserted that teachers with positive attitude, towards mathematics can stimulate favourable attitudes in their students.

Effect of technology on students' attitudes toward learning of mathematics

Studies examining this domain have shown strong links between students' attitudes towards the use of technology for learning mathematics and their achievements. To begin with, Shin, Sutherland, Norris and Soloway (2012), explored the effects of game technology on students learning in mathematics. The students' interview responses indicated that the technology-based game promoted positive attitudes toward learning and motivation. Moro so, the results from the quantitative studies provided evidence that game technology positively impacted students' learning of arithmetic regardless of ability level.

In another study, Pierce, Stacey and Barkatsas (2007) used the *Mathematics and Technology Attitudes Scale* (MTAS) to monitor and measure five variables relevant to learning mathematics with technology: mathematics confidence, confidence with technology, attitude to learning mathematics with technology, and behavioural and affective engagement in mathematics learning. They found that most of the 14-15 year old Australian students from all six schools surveyed agreed that it was better to learn mathematics with technology.

Barkatsas, Kasimatis and Gialamas (2009) also researched with the MTAS. They found out that, high achievement in mathematics was associated with high levels of mathematics confidence, strongly positive levels of affective engagement and behavioural engagement, high confidence in using technology and a strongly positive attitude to learning mathematics with technology and however, low levels of mathematics achievement was associated with low levels of mathematics confidence, strongly negative levels of affective engagement and behavioural engagement, low confidence in using technology, and a negative attitude to learning mathematics with technology.

The study by Curtis (2006) focused on students' perceptions about the nature of mathematics and learning mathematics. Students had a statistically significant change in their enjoyment of mathematics. The study identified that cooperative learning, problem-solving, discourse, and graphing calculators increased student confidence in doing mathematics because they felt more competent in working problems on exams. Students also found the class enjoyable, anxiety was reduced as students became more familiar with the instructional strategies, and students recognized the value of mathematics for job skills and personal business. Ellington (2003) also employed a meta-analysis to determine the effects of calculators on students' achievement and attitudes by integrating findings from 54 studies. The results revealed that students' operational skills and problem solving skills improved when calculators were used during testing and instruction.

Boyraz (2008) researched into the effects of computer based instruction on seventh grade students' spatial ability, attitudes toward geometry, mathematics and technology. Data on 57 seventh grade students were collected through spatial ability test, mathematics and technology attitude scale, geometry attitude scale, and interviews. The results revealed that the two methods of dynamic geometry based computer instruction had no significant effect on students' spatial abilities compared to traditional textbook based instruction. The results also indicated that two methods had a significant effect on students' attitudes toward geometry, mathematics and technology compared to traditional textbook based instruction. The results of the interviews indicated that computers created a dynamic learning environment which supported students' development and computers also helped students to explore transformation geometry in a far more meaningful way.

In relating the studies discussed so far to this study, the video-based instructional technology was not only meant to assist students in making sense of solid mensuration concepts, but to also play a vital role in promoting their positive attitudes toward learning and understanding solid mensuration.

Collaborative Learning

"Collaborative learning is an educational approach to teaching and learning that involves groups of learners working together to solve a problem, complete a task, or create a product" (Chandra, 2015, p. 4). Gokhale (1995), also said, "Collaborative learning refers to an instruction method in which students at various performance levels work together in small groups toward a common goal" (p. 1). From the definitions, it is clear that collaborative learning is based on students learning primarily through active engagement amongst them and learning occurs when the small groups help each other.

Characteristics of collaborative learning

According to Smith and MacGregor (1992), collaborative learning represents a significant shift away from the typical teacher-centered or lecture-centered milieu. In collaborative classrooms, the lecturing/listening/note-taking process may not disappear entirely, but it lives alongside other processes that are based on students' discussions and active work with the course material (p. 11). They added that teachers who use collaborative learning approaches tend to think of themselves less as expert transmitters of knowledge to students, and more as expert designers of intellectual experiences for students-as coaches … of a more emergent learning process (p. 11).

LeJeune (2003) added that successful implementation of collaborative learning must incorporate five critical components: common task, small-group interactions, collaborative behavior, positive interdependence, and individual and group accountability and responsibility. In the view of Chandra (2015), collaborative learning is based on the principles that: knowledge is a social construct; the learner or student is the primary focus of instruction; interaction and "doing" are of primary importance and working in groups is an important mode of learning (p. 4). According to Laal and Laal (2012), collaborative learning is based upon consensus building through cooperation by group members, in contrast to competition in which individuals best other group members (p. 439).

Benefits of collaborative learning

There are a number of benefits that are associated with students learning through collaboration. Laal and Ghodsi (2012) summarised the over 50 benefits for collaborative learning listed by Johnsons (1989) and Pantiz (1999) into four major categories of: social; psychological; academic; and assessment benefits (p. 487-488). First, on the social benefits, collaborative learning: helps to develop a social support system for learners; leads to build diversity understanding among students and staff; establishes a positive atmosphere for modelling and practicing cooperation, and; develops learning communities (p. 487). Bruffee (1984) noticed that, “collaborative learning provides the kind of social context, the kind of community, in which normal discourse occurs: a community of knowledgeable peers" (p. 644). Second, on the psychological benefits, collaborative learning: increases students' self-esteem; cooperation reduces anxiety; and; develops positive attitudes towards teachers (Bruffee, p. 487). The third benefits, academic: promotes critical thinking skills; involves students actively in the learning process; classroom results are improved; models appropriate student problem solving techniques; large lectures can be personalized; and helpful in motivating students in specific curriculum (Bruffee, p. 487-488). Last of all, collaborative teaching techniques utilize a variety of assessments (Bruffee, p. 488).

In looking at the impact of collaborative learning, Chandra (2015) contended that "educational experiences that are active, social, contextual, engaging, and student-owned lead to deeper learning" (p. 4). Chandra identified that collaborative environment promotes:

> development of higher-level thinking; oral communication; self-management and leadership skills; promotion of student-faculty interaction; increase in student retention; self-esteem and responsibility; exposure to and an increase in understanding of diverse perspectives; celebration of diversity; preparation for real life social and employment situations; (p. 4-5).

D'souza and Wood (2003) noticed that the entire focus of collaborative learning is to actively involve students in the learning process. In the process of exploratory learning, students attempt to solve a problem or answer a question (p. 4). Besides, "the use of collaborative learning strategies can make classroom life for instructors and students supportive, engaging, intellectually stimulating, creative, mathematically productive and fun" (D'souza & Wood, p. 8). In fact, "if the purpose of instruction is to enhance critical-thinking and problem-solving skills, then collaborative learning is more beneficial" (Gokhale, 1995; p. 30). According to Vygotsky (1978), students are capable of performing at higher intellectual levels when asked to work in collaborative settings than when asked to work individually.

Related research on collaborative learning

In 1995, Gokhale examined the effectiveness of individual learning versus collaborative learning in enhancing drill-and-practice skills and critical-thinking skills on series and parallel dc circuits. The two groups simultaneously received the same treatment, through lecture and worksheet task, but in separate classrooms. The study found out that students who participated in collaborative learning performed significantly better on the critical-thinking test than students who studied individually, however, both groups did equally well on the drill-and-practice test.

Similar to Gokhale's (1995) study, Chandra (2015) examined the influence of Collaborative learning and Individual learning on the achievement of English scores of 40 undergraduate students. Each learning group had 20 students. The results of the study showed that learning methodology influences the achievement in English. A significant difference was observed between the achievement scores in English of undergraduate students using Collaborative learning and individual learning methods. The achievement was higher for collaborative learning methods as compared to individual learning methods.

D’souza and Wood (2003) carried out a study on students' views about group work in mathematics. A combination of qualitative and quantitative methodologies was used to explore students’ experiences of group work in engineering mathematics. The study found out that collaborative learning had an overall positive effect in the cognitive domain as well as the social and affective domain.

Although this discussion has advanced numerous gains in support of collaborative learning, it should however be noted that, “placing students in a group and assigning them a task does not guarantee that the students will engage in effective collaborative learning behavior (Soller, 2001, p. 41-42). More importantly, “the most effective instructors teach students both the cognitive skills necessary to learn the subject matter, and the social skills they need to communicate well in a team (Soller, p. 42). It therefore suggests that, towards the successful implementation of collaborative learning, the teacher’s resourcefulness, effort and guidance to students before and during instruction is paramount.

Chapter Summary

The enactivist theoretical framework guided the classroom instructions; collection, analysis and interpretation of data; and the entire research process. In the enactivist classroom, teachers provide rich learning activities to help learners negotiate meaning towards acceptable and shared views (Begg, 2002, p. 8). Likewise, teachers build a rich learning world with abundant stimulation, but enough limits to guide students towards possible co-evolving patterns (Li, Clark and Winchester, 2010, p. 413).

It should be noted from the literature review on *Studies on Solid Mensuration Instruction with Technology*, that to the best of my knowledge, the use of videos for instruction in solid mensuration had not been given attention by researchers in the past and this necessitated the present study. Hence, within the context of the problem under study and Ghana in particular, I preferred using the videos to virtual manipulatives due to the following reasons. Agyei & Voogt (2011) pointed out that due to the complexity of problems most mathematics classrooms in Ghana face concerning ICT infrastructure and lack of application software, more generalised application that offers a technology readily available and user friendly among mathematics classroom to support students' higher-order thinking in mathematics is necessary (p. 436). Thus, both the YouTube videos and physical manipulatives are readily available to freely download. and safe or the videos could even be watched online during instruction. Again, teachers can easily teach with the video-based instruction even without professional training in technological pedagogy, than the virtual manipulates.

From the literature, there has not been a thorough investigation into students' attitudes toward the learning of solid mensuration with technology. However, clear understandings of these issues are essential for the effective integration of ICT in mathematics classroom. To ascertain students' tendency to collaborate in learning solid mensuration; the social, psychological and academic benefits of collaborative learning elaborated by Laal and Ghodsi (2012) were adopted.

CHAPTER THREE

RESEARCH METHODS

Introduction

This study drew upon the enactivist world view to explore the effectiveness of video-based instruction on students' relational understanding, their attitudes toward, and their tendency to collaborate in, learning solid mensuration. Enactivism as a research methodology is a theory for learning that follows the belief that a research process needs to take place from multiple perspectives in order to provide a holistic understanding of the phenomenon (Begg, 2002; Coles, 2007; Reid, 1996). An enactivist approach to research includes objectivism and subjectivism and therefore employs both quantitative and qualitative research methodologies to collect and analyse data (Begg, 2002). The discussion in this chapter follows these sub-headings: research design, population, sampling procedures, data collection instruments, pre-testing of instruments, validity and reliability of research instruments, enactment of video-based instructional lessons, data collection procedures, data processing and analysis, and ethical considerations.

Research Design

> Research designs are procedures for collecting, analysing, interpreting, and reporting data in research studies …. Rigorous research designs are important because they guide the methods decisions that researchers must make during their studies and set the logic by which they make interpretations at the end of studies (Creswell & Clark, 2007; p. 58).

Consequently, a mixed methods design, embedded with one-group pre-test and post-test quasi-experimental design was employed in this study.

Mixed methods designs are procedures for collecting, analysing, and mixing both quantitative and qualitative data in a single study or in a multiphase series of studies (Creswell 2012, p. 22). Mixed methods research involves collecting, analysing and integrating quantitative (e.g., experiments, surveys) and qualitative (e.g., focus groups, interviews) research (FoodRisC Resource Centre, 2016; para. 1). The reasons for using this design to investigate a research problem are well documented in literature. Hanson, Creswell, Clark, Petska and Creswell (2005) remarked that using this design in a study allows researchers to simultaneously generalize results from a sample to a population and to gain a deeper understanding of the phenomenon. Likewise, it is meant to bring together the strengths of the two databases to help compare results if there is convergence, differences, or some combination; validate results and corroborate results (Creswell, 2009). More so, this approach to research contributes a better exploration and understanding of the research question than either of each alone (Creswell 2012; FoodRisC Resource Centre, 2016). Among the different mixed methods designs, "concurrent triangulation strategy" (Creswell, 2012) was employed as the appropriate description of the overall design of this study.

Concurrent triangulation design

Hanson et al. (2005) gave the following explanations for this design:

> Quantitative and qualitative data are collected and analysed at the same time. Priority is usually equal and given to both forms of data. Data analysis is usually separate, and integration usually occurs at the data

interpretation stage. Interpretation typically involves discussing the extent to which the data triangulate or converge (p. 229).

According to Creswell (2012), the purpose of this design is to simultaneously collect both quantitative and qualitative data, merge the data, and use the results to understand a research problem (p. 540). Figure 6 shows the visual diagram of the concurrent triangulation strategy used in this study.

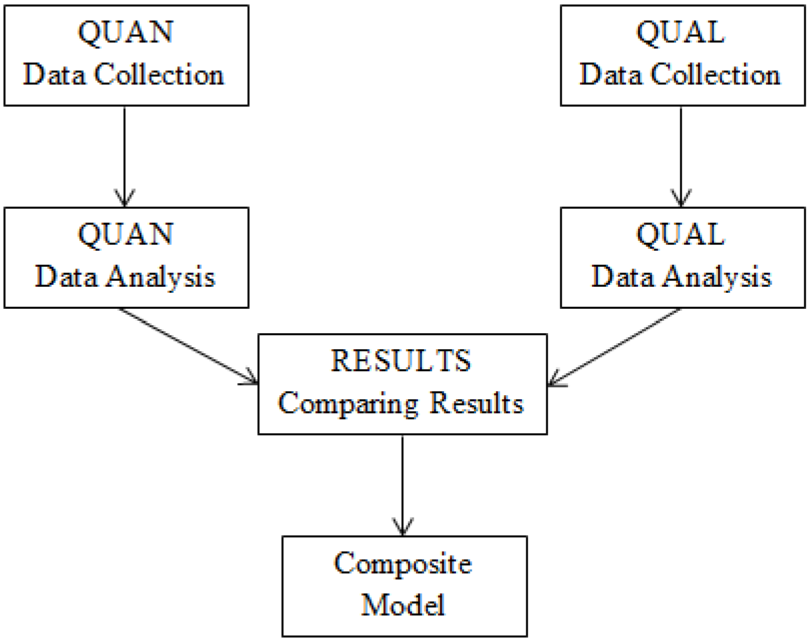


Figure 6. Visual model of the concurrent triangulation design
Source: Creswell, 2012, p. 541

This design was used because of the following reasons (Creswell, 2009; Creswell, 2012; Creswell & Clark, 2007; Hanson et al., 2005). The design is useful to confirm, cross-validate and corroborate study findings — resulting in well-validated and substantiated findings. One data collection form supplies strengths to offset the weaknesses of the other form, that is, quantitative data provide for generalizability, whereas qualitative data offer information about the context or setting. It is an efficient design, in which both types of data are collected during one phase of the research at roughly the same time, and triangulating the data from different methods increases the validity of the results and the conclusions.

Although this design is the most popular mixed methods design, it has some challenges. It requires much effort and expertise, because of the concurrent quantitative and qualitative data collection. Another challenge is what to do if the quantitative and qualitative results do not agree (Creswell & Clark, 2007). “One difficulty with this design is how to merge the two forms of data, and, when this is done, to determine how to assess results that diverge” (Creswell, 2012, p. 542).

The intent for using a mixed methods concurrent triangulation design in this ‘enactive’ study was to collect and analyse quantitative and qualitative data separately on the research problem and compare the results, to validate, confirm, or corroborate the quantitative results with the qualitative findings; and merge the results at the interpretation stage (Creswell & Clark, 2007).

One-group pre-test and post-test quasi-experimental design

The concurrent triangulation mixed methods design was embedded with the one-group pre-test and post-test quasi-experimental design, which was used at the quantitative phase of the study. In the one-group pre-test and post-test design, “a single pretest observation is taken on a group of respondents (O_1), treatment (X) then occurs, and a single posttest observation on the same measure (O_2) follows: O_1 X O_2” (Shadish, Cook & Campbell, 2002, p. 108). In connection with this study, to ascertain the effectiveness of the video-based instruction; the participants were pre-tested by answering the before instruction questionnaire; followed by the treatment, that is, enactment of the nine video-based instruction lessons on solid mensuration; and then, they were post-tested by answering the after instruction questionnaire. Both the before and after instruction questionnaire had the same information.

Another approach followed in this study was to conduct the same study in the two schools (with one intact class each), by using the same video-based instruction, methodologies and analysis. This approach was used because of the following advantages it has over a single study, using the one-group pre-test and post-test quasi-experimental design without control group, to study the problem under consideration. Ruane (2005) pointed out that if research findings are true, then they should show up time after time under similar research conditions when the study is repeated as one-time findings are usually too good to be true. Likewise, Fraenkel, Wallen & Hyun (2012) added that repeating a study with a number of similar samples is to decrease the likelihood that the results obtained were simply a one-time occurrence. More so, if consistent findings are obtained from repeated studies, it bolsters the confidence of the researcher in the reliability and generalizability of the original findings (Ruane, 2005 & Fraenkel et al., 2012).

In this study, the video-based instruction (teaching method/treatment) was the independent variable manipulated to affect the three dependent variables: students' relational understanding, students' attitudes, and students' collaborative learning; of solid mensuration.

Population

The location for the study was the Birim Central Municipality found in the Eastern Region of Ghana. The study involved all Senior High/Technical Schools students in the municipality. Yin (1989) called attention that researchers must select sites and participants that will contribute to the research and also provide further information to the research. Audet and D'Amboise (2001) pointed out that researchers select a site because of its convenience, accessibility and geographical proximity. Others select a site which they think may yield similar results or different results to answer the research questions raised.

In the present study, the Birim Central Municipality was chosen for this study because of convenience and geographical proximity. The selection of this site also produced both similar and divergent results, leading to a deeper understanding of the problem under investigation (Audet and D'Amboise 2001). As of the time of the study, the Birim Central municipality had seven co-educational Senior High/Technical schools, of which two were private and the rest were public (GES, 2016). The schools had both boarding and day students, with the students having diverse demographic characteristics as they were from different places in Ghana.

Sampling Procedures

Participants for the study comprised third year students in the Birim Central municipality. These students were considered ideal for the study due to the following reasons. As said earlier, from both the Core Mathematics curricula and previous WASSCE questions on solid mensuration; for effective teaching and learning, students must have prior knowledge of the following topics: *Change of Subject of an Equation*, *Plane Geometry I*, *Trigonometry I*, *Enlargement* (*Areas* and *Volumes of Similar Figures*) and *Mensuration I*. Thus, the final year students had covered most of these topics compared to first and second year students. As of the period of the instructional stage (second term of the 2016/2017 academic year), the final year students were preparing for their final examination and therefore, it was reasonable that they would need the knowledge on solid mensuration most than the first and second year students.

The sampling procedures for this study were in three stages. In each stage too, random sampling using Trek (2016) random number generator was used. This was used to eliminate bias and also give equal opportunities to each participant. Firstly, the two schools (M & N *pseudonymous*) were selected from schools with computer labs for instructional part of the study. The labs had the needed ICT instructional facilities (i.e., computers, projector, projector screen and white marker board). Though the selected schools were interested in the study, they however allowed me to engage the students during prep time (both working days and Sundays between 7:00 pm to 9:00 pm).

Next was the selection of one intact class each from each of the third year classes in the two schools. The reasons for using intact classes were to ensure that all participants benefited from the lessons. Dimitrov and Rumrill (2003) also reasoned that the use of intact groups does not disrupt the existing research setting, but keeps the participants in their natural settings. Hence, it reduces the reactive effects of the experimental procedure and this allows a higher degree of the external validity of the research design. Schools M and N offered similar programme (i.e., General Arts, Business, Home Economics, General Science, Agriculture, Technical and Visual Art). School M had 476 third year students and 12 classes, while School N had 511 third year students and 14 classes.

According to Fraenkel et al. (2012) for experimental studies, a minimum of 30 individuals per group is recommended. The classes in each school were serially arranged. A class was selected from each school, making sure the class size conforms to Fraenkel et al. benchmark. Afterwards, I met the students of the two selected classes (3 Science from School M and 3 General Arts 2 from School N) and briefed them on the study. Interested students voluntarily completed the consent form. All the students were interested in the study, only that the prep time for instructions did not favour the six day students in Class N of School N. Hence, they did not consent to the study. The demographic characteristics of the sample of students involved in the study are shown in Table 2.

Table 2: Demographic Characteristics of Students

	Class M		Class N	
Gender	N	%	N	%
Male	32	74.4	21	53.8
Female	11	25.6	18	46.2
Total	**43**	**100**	**39**	**100**

From Table 2, participants from School M involved in the study were 43, with 32 males and 11 females and average age of 17 years. School N had 39 participants with 21 males, 18 females and average age 18 years.

The last stage of the sampling involved the selection of 10 interviewees from each of the two classes for in-depth interviews and answering of solid mensuration question. The selection was based on students who had participated and also took part in the class tests in all the nine lessons.

Data Collection Instruments

Likert scale questionnaire and written tests questions (quantitative data), and semi-structured interview guide (qualitative data) were used to collect data from the participants to answer the research questions that guided the study. The written tests were conducted at the end of each of the nine lessons. Students present answered test, which assessed their individual level of understanding and performance in the day's lesson. Each test was marked and scored out of 10 marks.

Questionnaire

The questionnaire was aimed at collecting information on the students' thoughts and experiences before and after the instructions. The students assessed their own relational understanding, attitudes and their tendency to collaborate upon receiving instructions in solid mensuration through the use of video-based instruction. According to Petrou (2007), the use of a questionnaire has a number of advantages. First, it presents all respondents with identical items providing a high level of comparability among the respondents. Second, it can be administered to a representative sample. This means that the statements on each of the three issues considered in the study were more likely to be generalised. However, the closed-ended questions did not say much of what the participants mean or how they thought in their response to a statement. Therefore, the interview data was used to fill out the questionnaire data.

The questionnaire was divided into four sections; A, B, C and D. Section A elicited each student's personal biographic data on age and gender. Sections B, C and D had 55 statements on a 4-point Likert scale response format (*Strongly Agree=4, Agree=3, Disagree=2 and Strongly Disagree=1*). The scores were interpreted as follows: 4, the highest possible score indicating a very strong positive response, with 1 being the lowest possible score indicating a very strong negative response. All statements in the questionnaire were positively worded. The questionnaire statements were drawn from previous studies' instruments; however there were some minor modifications in terms of language structure and terminologies. The before instruction questionnaire (Appendix C) was framed in the future tense and the after instruction questionnaire (Appendix D) was framed in the past tense.

One of the main advantages of using a 4-point Likert scale is that it limits the respondents' choice to either agreeing or disagreeing to a statement and Nworgu (1991) argued that a 5-point Likert scale gives room for undecided responses. However, not only does a 4-point scale response format improve the statistical strength of the results, a weight of three to undecided responses is considered to be illogical and would make the data analysis inefficient (Swan, 2006). Therefore, the 4-point Likert scale was considered to be appropriate for this instrument for the purpose of efficiency in the data collection and analysis process.

Section B of the questionnaire elicited students' response on how the use of video-based instruction improved their learning and understanding of solid mensuration concepts. It had 15 items adapted from Agyei (2012; p. 237) and Lestari and Hernawati (2014; p. 662). The adaptations involved changing spread sheet to videos and ICT-based media to video-based instruction.

Section C was used to gather data on students' attitudes toward learning with video-based instruction. The 15 items were adapted from Pierce et al. (2007) *Mathematics and Technology Attitudes Scale* (*MTAS*). The MTAS consist of 20 items on five sub-scales measuring: Mathematics Confidence (MC); Confidence with Technology (TC); Affective Engagement (AE) and Behavioural Engagement (BE). The Confidence with technology sub-scale was not considered as participants for the study did not personally use the computers during lessons. Some of the adaptations involved changing mathematics to solid mensuration and graphic calculators to videos. The MTAS questionnaire has satisfactory Cronbachs alpha values for each subscale (MC, 0.87; MT, 0.89; TC, 0.79; BE, 0.72 and AE, 0.65), indicating acceptable degree of internal consistency in each subscale (p. 294). The authors of MTAS also affirmed that the content validity and face validity of the scale in terms of suitability of items are assured as many were derived from previously published scales.

Section D of the questionnaire was to gather data on the effect of video-based instruction on students' tendency to collaborate in learning solid mensuration. It had 25 items adopted from the Student Attitudes toward Group Environments (SAGE) questionnaire which has 54 items. Kouros, Abrami, Glashan and Wade (2006) established a high content validity and overall Cronbach alpha reliability value of 0.93 for the SAGE questionnaire.

The Cronbach alpha coefficient reliability values of the pre-tested questionnaire for the various constructs exceeded the acceptable value of 0.7 (Pallant, 2007), suggesting that the items had good internal consistency, so the scales could be considered reliable with the sample used.

Semi-structured interview guide

Fincher and Petre (2004) defined interviews as "guided dialogues, valuable in eliciting subjects' experiences, perceptions, opinions, attitudes, intentions, and beliefs" (p. 53). According to them, interviews allow subjects to: (1) respond in their own words, (2) explain behaviours in terms of their own values, goals, and expectations, (3) assign their own meanings, and (4) provide clarification (p. 53). For this study, the individual semi-structured interview was preferred for two main reasons. Firstly, to find answers to the research questions, the individual interview was to help gain an in-depth understanding of the experiences of the individual interviewee. Secondly, confidentiality and anonymity were the two main ethical considerations with which this study strived to protect students' responses and identities.

The interviews were conducted using an interview guide (see Appendix E). The questions were aligned with the research questions, and most of the questions were drawn from the questionnaire instrument in order to facilitate the data triangulation during the analyses. According to Patton (2002), the interview guide ensures that; the same basic lines of inquiry are pursued with each interviewee, the interviewer is free to explore, probe and ask questions that will clarify the particular subject, and the interviewer makes best use of the limited time available. Its usage ensured uniformity, consistency, helped to structure the interview and helped to obtain rich data from the interviewees.

Table 3 presents the data sources used to answer each research question.

Table 3: Research Design Matrix

Research Questions	Type of Data	Instruments
1. What is the effect of video-based instruction on students' relational understanding of solid mensuration?	Quantitative Qualitative	Questionnaire, Tests Scores Solid Mensuration Task
2. What is the effect of video-based instruction on students' attitudes toward learning solid mensuration?	Quantitative Qualitative	Questionnaire Interview Guide
3. What is the effect of video-based instruction on students' tendency to collaborate in learning solid mensuration?	Quantitative Qualitative	Questionnaire Interview Guide

Pre-Testing of Instruments

A pilot study was carried out during the first term of 2016/2017 academic year on another school within the Birim Central Municipality — this school was not selected for the main study. The school had similar characteristics with the two schools in the main study. It was a public school, mixed sex school, both day and boarding school and had a computer lab with the necessary resources to accommodate the video-based instruction. A class of 40 students was used for the pilot study. The pilot study was conducted to pre-test the instruments for the research, by checking whether the instructions and wording of the items in the questionnaire and interview guide were comprehensible and to establish the reliability and validity of the instruments.

It was also used to pre-test the designed lessons in order to identify and improve upon the shortcomings before the instructional stage of the research.

The Likert scale questionnaire was administered to the group before-instruction and after-instruction. Three questions on collaborative learning were dropped as they were repeating the same idea. The number of items and Cronbach alpha reliability coefficients of the three constructs for the before instruction and after instruction are reported in Table 4.

Table 4: Reliability Coefficients of Constructs of Questionnaire

Constructs	№ of Items	Cronbach Alpha Reliability Coefficients	
		Before Instruction	After Instruction
Relational Understanding	15	0.773	0.784
Attitude	15	0.775	0.880
Collaborative Learning	25	0.895	0.944

From Table 4, the Cronbach alpha coefficient reliability values were within the acceptable value of 0.7 (Pallant, 2007), indicating acceptable and good degree of internal consistency in each construct.

I taught the class the seven lessons, all at evening preps as arranged for the main study too. Some weaknesses were observed in the instructional design and they were corrected. Firstly, some of the lessons were over loaded in terms of the lesson objectives, students' activities and evaluation test, thus these lessons could not accommodate the normal 80 minutes duration. I therefore restructured the lessons into 9 of 80 minutes duration each.

Secondly, some of the videos had poor audio or visual quality. So, new videos were downloaded, screened to the students, which met their approval, in terms of the videos quality. Lastly, some of the information on the PowerPoint slides was not well aligned with the students' activities sheet instructions. Those lessons were re-aligned.

After all the instruction, I selected and interviewed three of the students. This helped in rewording and structuring some of the questions. This eased interviewees' understanding; thereby eliciting right and rich responses from them. The pre-testing of the research instruments ensured that the refined instruments were into more simple language for clarity and understanding of respondents before the final instrument was administered. It was also noted that most of the items in the questionnaire were relevant in the Ghanaian context and met the purpose of the study.

Validity of research instruments

"A valid study is one that has properly collected and interpreted its data, so that the conclusions accurately reflect and represent the real world (or laboratory) that was studied" (Yin, 2011, p. 78). Validity also refers to the appropriateness, meaningfulness, correctness, and usefulness of the inferences a researcher makes based on the collected data (Fraenkel et al., 2012). In simple terms, to ensure validity, a research instrument must measure what it was intended to measure (Gray, 2004; p. 90). In order to enhance the validity and evaluate the trustworthiness of the results of this study, the following measures were employed.

Questionnaire: I ensured that the questionnaire statements were aligned with the research questions and comprehensively cover the details of the study

(Cohen et al., 2007 & Gray, 2004). The research instrument was given to my two supervisors for their expert evaluation. Checks were made on the clarity of statements, appropriateness of language and clarity of constructions. The pre-testing of the instrument also ensured that some statements had to be restructured for easy understanding of the respondents. The relevant suggestions were incorporated to refine and improve both the face and content validity of the instrument before the main study.

Videos: The videos were used as both cognitive and instructional tool in the designed lessons on solid mensuration. Hence, I pre-tested the videos and I had to replace some of them. As a result, the videos used in the lessons had clear sound and visual quality and were also specific in the realisation of the instructional objective(s) intended to answer.

Semi-structured interview guide: I ensured that the interview questions were aligned with the research questions. The interview guide was given to my two supervisors for their expert evaluation. Checks made in terms of the clarity of statements and constructions, and whether the questions effectively capture the topic under investigation. I incorporated their suggestions to refine and improve both the face and content validity of the instruments before pre-testing it. During the pre-testing of the interview guide, I had to restructure some of the questions to aid students' understanding and elicit the right responses. This helped to improve the validity of the instrument. What is more, the use of audio recorders in recording interview information ensured that I obtained accurate and verbally exact statements of respondents which provided concrete evidence of my findings.

Internal validity was met using the following strategies. I collected different sources of data (questionnaire, interviews and written work scripts) and used triangulation of data. This helped to minimise the limitations posed by the use of one particular method. Moreover, internal validity was confirmed through appropriate record keeping. Lastly, I conducted the research using intact classes and in the participants own school. This natural setting promoted the reality of the participants' experiences more accurately.

In the study, external validity was achieved through the use of multiple sources of data and the in-depth description of the context of the study and the data collection and analysis procedures.

Reliability of research instruments

Reliability is the consistency of the scores or answers obtained from one administration of an instrument to another, and from one set of items to another (Fraenkel et al., 2012). For research to be reliable it must demonstrate that if it were to be carried out on a similar group of respondents in a similar context, then similar results would be found (Cohen et al., 2007, p. 117). The following strategies were used to ensure that my findings were reliable. To begin with, from the results of the pre-test of the questionnaire instrument reliability coefficients values computed using the test-retest approach, both the before and after instruction questionnaire data reliability coefficients were higher than the acceptable threshold, showing that the scales are reasonably consistent and reliable. Also, I coded all the data collected which ensured consistency of the coding strategy. Then, I ensured that my position was as a researcher and I had no influence in relation to my biases to the data collection and analysis.

According to Merriam (2009), triangulation remains a principal strategy to ensure for validity and reliability (p. 216). Hence, the use of triangulation or multiple methods of data collection and analysis strengthened the reliability as well as internal validity. Finally, the detailed report of the data collection and analysis strategies helped to provide a clear and accurate picture of the methods used in this study.

Enactment of Video-Based Instructional Lessons

In this study, video-based instruction was the teaching method used to investigate its effect on; students' relational understanding of solid mensuration, their attitudes, and their tendency to collaborate in learning solid mensuration. Table 5 shows the nine lessons I enacted in the two classes.

Table 5: Solid Mensuration Lessons Sequence

Lesson	Sub-Topic/Content
1	Introduction to Solid Mensuration
2	Drawing Solid Shapes and Net Surfaces
3	Surface Area of Polyhedrons
4	Surface Area of Non-Polyhedrons
5	Volume of Polyhedrons
6	Volume of Non-Polyhedrons
7	Finding Lengths and Angles inside Solid Shapes
8	Volume and Surface Area of Composite Solid Shapes
9	Frustum, Similar and Changed Solid Shapes

The sub-topics listed in Table 5 and the instructional objectives for the lessons were drawn from: (1) the teaching curriculum (MoE, 2010); (2) examination curriculum (WAEC, 2014-2020); (3) WAEC chief examiners comments on candidates' weaknesses and mistakes on solid mensuration questions and (4) literature reports on students' misconceptions and errors when learning solid mensuration, as discussed in Chapters One and Two. The lesson objectives were tailored to the Bloom's Taxonomy (Krathwohl, 2002); so, students thinking progressed from the lowest to the highest levels. Sample lesson plan and the students' activities sheets are in Appendix F and G.

Context of video-based instruction

The lessons were implemented using a modified context of Cohn and Ball (2000) instructional context (see Figure 7).

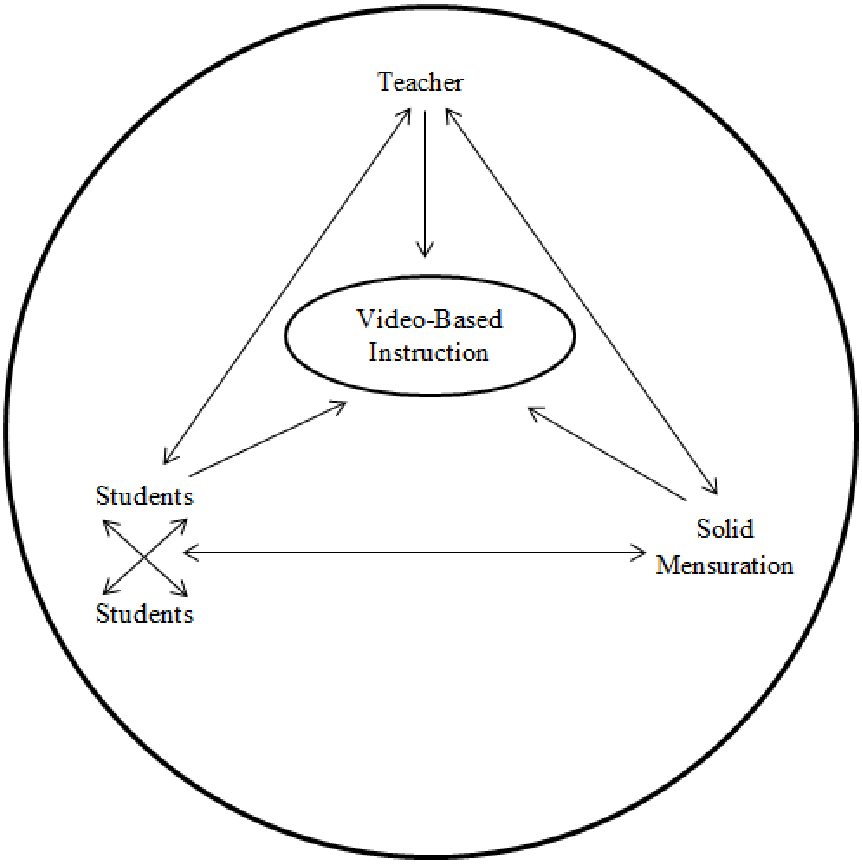


Figure 7. The context underlying enactment of video-based instruction.

The instructional context in Figure 7 is explained based on the ideas of Kilpatrick, Swafford and Findell (2001). They contended that:

> All forms of instruction can best be examined from the perspective of how teachers, students, and content interact in contexts to produce teaching and learning. The effectiveness of mathematics teaching and learning is a function of teachers' knowledge and use of mathematical content, of teachers' attention to and work with students, and of students' engagement in and use of mathematical tasks (p. 8-9).

Kilpatrick et al. (2001) viewed the teaching and learning of mathematics as the product of interactions among the teacher, the students, and the mathematics in an *instructional triangle* (p. 313), as illustrated in *Figure 7*. Figure 7 shows the interactions among the four elements embedded in a context: video-based instruction, teacher, students and solid mensuration. The interactions illustrated with one and two sided arrows, shows how interactions occurred in students' knowledge construction. At the centre of the triangle is video-based instruction, indicating the instructional method employed. The one sided arrows show the three elements: teacher, students and solid mensuration dependence on the video-based instruction. The interactions illustrated with two sided arrows, shows that the interactions occurred bidirectional in the teaching and learning process. By this, interactions happened between teacher-and-students and students-and-students. The instructional context also addressed students' engagement and learning through collaborative learning.

Mishra and Koehler (2008) indicated that Content Knowledge (CK), Pedagogical Knowledge (PK) and Technological Knowledge (TK) are the three core knowledge needed for effective technology integration. Hence, these core knowledge were integrated in the lessons, with the content knowledge embedded in the videos.

At the end of each lesson, the students' present were assessed on a written test. This was followed by homework. Each test was marked and scored out of 10.

Data Collection Procedures

The mixed methods concurrent triangulation design is a single-phase design which involves the concurrent, but separate, collection and analysis of quantitative and qualitative data to best understand the research problem (Creswell & Clark, 2007; p. 64). The entire data collections and instruction were simultaneously carried out in the two schools in the second term of the 2016/2017 academic year, which lasted about eight weeks. On 16th January, 2017 the students in school N consented to participate in the study and then I administered the before instruction questionnaire. This was similarly done in school M on 18th January, 2017. This was followed by the instructions, where I taught the nine solid mensuration lessons in the two schools for five weeks. At the end of each lessons, students present answered written test, which was marked and scored out of 10 marks.

After the instructional period, I administered the after instruction questionnaire, which ended the quantitative phase of the data collection. Students spent a longer time, averagely 35 minutes to answer the before instruction questionnaire since they were unfamiliar with some of the words related to the video-based instruction, but it took them an average of 20 minutes to answer the after instruction questionnaire. The final week was used to collect the qualitative data (conduct of interviews). The selected interviewees all participated and took part in all the tests in the nine lessons. The reasons for using these criteria were to obtain fair and credible information from them, since they had personally experienced and received instruction in all the solid mensuration lessons. Though 10 participants were selected from each class to be interviewed some declined. Of those interviewed too, some of them could not give complete and clear information to some of their responses, therefore; their reports were not captured in the analysis. So, the interview report analysis presented in Chapter Four was on 10 interviewees, 5 from each class. All the interviews were audio-recorded and each interview lasted between 30 to 40 minutes.

Data Processing and Analysis

Data analysis is the process of making sense out of the data which involves consolidating, reducing, and interpreting the data. It is the process used to answer your research question(s) (Merriam, 2009; p. 175-176). According to Creswell and Clark (2007), one of the procedures used for mixed methods research data analysis is concurrent data analysis, whereby both the quantitative and qualitative data are analysed separately. They explained that this data analysis procedure "involves the concurrent, but separate, collection and analysis of quantitative and qualitative data so that the researcher may best understand the research problem" (p. 64).

In this study, the quantitative and qualitative data were collected and analysed separately, then the results were compared side by side during the discussion, by first presenting the quantitative statistical results followed by the qualitative results that support the quantitative results. I also used tables and snapshot pictures of interviewees work scripts as visual representations in presenting and displaying the data to summarise the quantitative and qualitative datasets to make the data meaningful and easy to understand and interpret (Creswell & Clark, 2007). Broadly speaking, in finding answers to my research questions, both the quantitative and qualitative data sets were analysed inductively to allow categories, themes and patterns leading to sets of smaller and similar data that were more workable. The use of the inductive process helped in determining links between the categories … (Merriam, 2009; p. 15-16). This approach also provided a rigorous and standardised way of achieving high validity in terms of the study results (Patton, 2001).

Quantitative data analysis

The students' responses to the before and after instruction questionnaire and lessons test scores data were entered into Microsoft Excel and transported into SPSS (version 21). The questionnaire data were coded and categorised into sub-categories or themes. Descriptive and inferential statistics were used to analyse the quantitative data. The paired sample *t*-test was used to compare and test the statistical significant mean difference between the paired data set of students' views before and after instruction. In order to quantify the size of the statistical significance of the mean differences, the Cohen's *d* effect sizes were also determined as recommended by Coe, 2002 and Sun, Pan & Wang, 2010. These values were interpreted using Cohen (1992) magnitude of the effect sizes benchmarks: *d* (0.20) = a small effect; *d* (0.50) = a medium effect and *d* (0.80) = a large effect. Data analysis of students' performance based on their relational understanding of solid mensuration was analysed using each student's mean score (i.e., student's total score in all the number of written tests participated in, against the number of test participated in).

Qualitative data analysis

The qualitative phase of the study was used to provide in-depth qualitative study to explain why the quantitative results occurred. This was based on interview reports and worked scripts of ten participants. Data reduction technique and content analysis were used to analyse the audio-recorded interviews and worksheet data. “Data reduction refers to the process of selecting, focusing, simplifying, abstracting, and transforming the data that appear in written up field notes or transcriptions” (Miles & Huberman, 1994). Content analysis is an approach to the analysis of documents and texts (which may be printed or visual) that seeks to quantify content in terms of predetermined categories and in a systematic and replicable manner (Bryman, 2012). Scoring rubrics (see Appendix H) was designed and used in scoring interviewees answers to interview Questions 8 and 10.

Research question 1: What is the effect of video-based instruction on students' relational understanding of solid mensuration? The Section B of the questionnaire had 15 statements categorised as follows: *Spatial Ability of Solid Shapes* (Statements 1, 10 and 12), *Conceptual Knowledge of Solid Mensuration* (Statements 2, 4, 5, 7, 8, 9 and 15) and *Real-Life Connections* (Statements 3, 6, 11, 13, and 14). From the interview guide, Questions 2, 5, 8, and 10 reflected Research Question 1. For that matter, interviewees' responses to these questions were thoroughly examined and appropriately classified under the themes.

Research question 2: What is the effect of video-based instruction on students' attitudes toward learning solid mensuration? The Section C of the questionnaire had 15 statements categorised into four as: *Behavioural Engagement* (Statements 1, 2, 3 and 4), *Affective Engagement* (Statements 8, 9, 10 and 11), *Solid Mensuration Confidence* (Statements 5, 6 and 7) and *Solid Mensuration with Videos* (Statements 12, 13, 14 and 15). From the interview guide, Questions 1, 3, 4 and 9 centred on Research Question 2. Hence, interviewees' responses to these questions were organised into themes to reflect the quantitative categorises.

Research question 3: What is the effect of video-based instruction on students' tendency to collaborate in learning solid mensuration? The Section D of the questionnaire had 25 statements. The statements were categorised into three as: *Social Benefits* (Statements 1, 3, 7, 11, 12, 16 and 19), *Psychological Benefits* (Statements 4, 5, 9, 10, 13, 14, 15 and 23) and *Academic Benefits* (Statements 2, 6, 8, 17, 18, 20, 21, 22, 24 and 25). Looking at the interview guide, Questions 6 and 7 were related to Research Question 3. Therefore, interviewees' responses to these questions were grouped under the same themes as the quantitative data: *Social Benefits*, *Psychological Benefits* and *Academic Benefits*.

Ethical Considerations

Ensuring the validity and reliability of a research process involves conducting the investigation in an ethical manner (Merriam, 2009). According to Creswell (2012), in mixed methods research ethical considerations need to address both quantitative and qualitative forms of inquiry (p. 553). Quantitative issues relate to obtaining permissions, protecting anonymity of respondents, not disrupting sites, and communicating the purposes for the study. Qualitative issues relate to conveying the purpose of the study, avoiding deceptive practices, respecting vulnerable populations, being aware of potential power issues in data collection, respecting indigenous cultures, not disclosing sensitive information, and masking the identities of participants. As much as possible, these issues were taken into account during the research.

I first visited the selected schools to familiarise myself with the environment within which lessons were delivered. With the aid of the introductory letter (see Appendix A), I explained the purpose of the research to all concerned parties in the two selected schools. I was granted permission to conduct the research. Afterwards, I met the students and made them aware of the purpose of the study, the meeting days and time schedules for the lessons. They then filled the consent form (see Appendix B). Lastly, I assigned the participants with unique serial codes. Hence, the data used in this study was anonymously coded and cannot therefore be traced back to individual participants.

Chapter Summary

This chapter discussed the mixed methods concurrent triangulation design, with one-group pre-test and post-test quasi-experimental design. The chapter explained the rational for repeating the study in the two intact classes from the two schools. The chapter further discussed the population, participants, research instruments, lessons enactment and the procedures used in data collection data. Issues on validity and reliability of the instruments and research were also dealt with. Finally, the chapter outlined the ethical considerations, as well as the measures taken to minimise and address them.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

The aim of this study was to explore the effect of video-based instruction on students' relational understanding, their attitudes toward the use of video-based instruction, and their tendency to collaborate, in learning solid mensuration; in the Birim Central Municipality. The study employed concurrent triangulation mixed methods design; using on one-group pre-test and post-test quasi-experimental approach, in two intact classes from two schools. This chapter presents the results that emerged from the analyses of the data collected from the two intact classes. To facilitate the comparison of the quantitative and qualitative results, both data sets were analysed under the same themes (sub-constructs), and the qualitative data used to validate and strengthen the quantitative results. This was followed by synthesising the similar findings that emerged from the two intact classes' results, which were used to answer the research questions; and the discussion of findings of the study in reference to the literature.

School M Data Analyses Results

All the 43 intact class participants of this school responded to the before and after instruction questionnaire. Afterwards, five of the interviewees' reports and work scripts were analysed and the results used to confirm the quantitative results.

Research Question 1: What is the effect of video-based instruction on students' relational understanding of solid mensuration?

Quantitative data: The results in Table 6 compare the students' self-assessment of the effectiveness of the use of video-based instruction in learning solid mensuration before and after instruction.

Table 6: Paired Sample t-test of M Students' Self-Assessment of their Relational Understanding of Solid Mensuration (N=43)

Relational Understanding	Before Instruction		After Instruction		*p* value	Effect Size (*d*)
	M	*SD*	*M*	*SD*		
Spatial Ability of Solid Shapes	1.54	0.357	3.75	0.283	0.0001	6.20
Conceptual Knowledge of Solid Mensuration	1.54	0.289	3.65	0.258	0.0001	6.36
Real-Life Connections	1.51	0.294	3.72	0.255	0.0001	6.05
Overall Relational Understanding	**1.53**	**0.259**	**3.71**	**0.223**	**0.0001**	**7.79**

Significance level, $\alpha = 0.5$; Degrees of freedom, $df = 42$

The results in Table 6 show positive mean gains for all the sub-constructs with overall mean gain of 2.18 between the after instruction $M = 3.71$ and before instruction $M = 1.53$. There was a statistically significant mean difference in the sub-constructs and overall mean relational understanding of solid mensuration before instruction ($M = 1.53$, $SD = 0.256$) and after instruction ($M = 3.71$, $SD = 0.223$), $t\ (42) = 50.56$, $p < 0.001$. The Cohen's d effect size, $d = 7.79$ indicates a large effect size. Therefore, this substantial difference could be attributed to the use of the video-based instruction.

Table 7 presents the results of the students' performance in the nine lessons tests conducted.

Table 7: Descriptive Statistics of M Students' Lessons Tests Scores

n	Min. Score	Max. Score	Median Score	Mode Score	Mean Score	SD	Skewness	Kurtosis
43	6.44	10.00	8.29	8.63	8.24	0.74	0.14	0.49

Table 7 reveals that the mean score of students in the tests was 8.24 (SD = 0.74), with 23 students (53.49%) scores above the mean score; whereas the maximum score was 10 out of 10 and minimum score was 6.44, giving a range of 3.56. The skewness value 0.14 and kurtosis value 0.49 which are within ±1.00 (Bluman, 2004; Huck, 2012) indicate nearly normal distribution of scores. The positive results on students' performance could be attributed to the use of the video-based instruction, which confirms the results of their self-assessment of their relational understanding of solid mensuration.

***Qualitative data*:** The interviewees' reports and written answers were grouped under the same sub-constructs as the questionnaire data analysis. The interviewees demonstrated their spatial ability skills and conceptual knowledge in responding orally followed by written response to the interview Questions 2, 8 and 10 (see Appendix E). A scoring rubric (see Appendix H) was used to score their responses for the Question 10 (solid mensuration task).

The results in Table 8 compare their scores in the lessons tests to the solid mensuration task. Lessons tests score of three of the students selected for interview were below the class mean score of 8.24, whereas student M33 had a maximum score of 10 out of 10 in the nine tests.

Table 8: M Interviewees' Scores in Lessons Tests and Solid Mensuration Task

Students	Gender	Lessons Tests Score	Solid Mensuration Task Score
M33	Male	10.00	10.00
M23	Female	9.11	9.33
M10	Female	8.11	10.00
M05	Male	7.56	10.00
M43	Male	7.44	10.00

Before answering the solid mensuration task, interviewees were asked if they could confidently answer solid mensuration question in any given test and perform well. Apart from student M10, the rest responded in the affirmative. However, looking at Table 8, it turned out that student M10 was among the four interviewees who scored 10 out of 10.

The following are excerpts and snapshots of interviewees' responses expressing their development of spatial ability and conceptual understanding as a result of learning solid mensuration with video-based instruction.

Spatial ability of solid shapes**:** On the solid mensuration task (*A pile of sand is in the form of cone of base diameter 3 m and height 2 m. It is used to fill a rectangular jumping pit measuring 2.4 m by 1.9 m*), interviews were to: *Oral Understanding;* (a) Identify the properties of each solid shape in the given information, and *Written Understanding*: (a) Draw and name each solid shape in the given information. Figure 8 indicates that student M05 was able to identify at least three properties of cone and cuboid, and clearly draw and label the two shapes as required by the scoring rubrics. The rest are captured in Appendix I.

10 (a) ***Oral Understanding***

Cone*: a circular base, one vertex, a curved surface and one circular edge.*
Cuboid*: 6 faces, 12 edges, 8 vertices and a rectangular base.*

Written Understanding

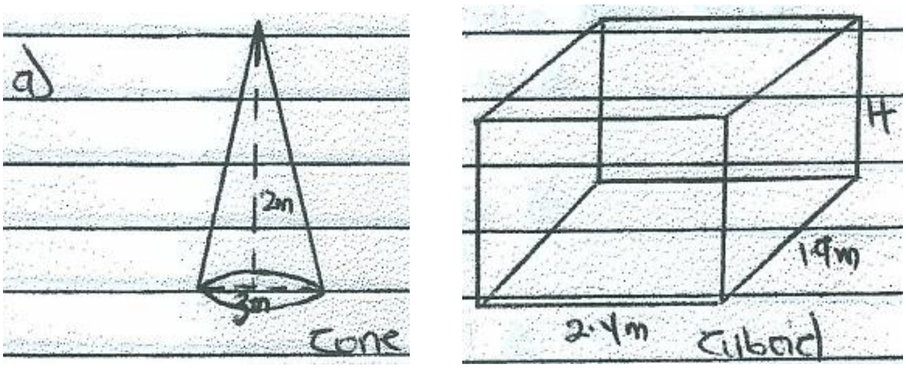


Figure 8. Excerpt and snapshot of student M05 answer to question 10 (a).

From the interviewees' solid mensuration task scores and sample work sheets, it is clear that the use of the video-based instruction with physical manipulatives enhanced the students spatial ability of solid shapes, more specifically, their spatial orientation (three-dimensional experience) and spatial insight (two-dimensional experience).

Conceptual knowledge of solid mensuration**:** From the interview guide, interviewees answers to Questions 2, 8 and 10 (b) and (c) were put together to find out their development of conceptual knowledge of solid mensuration. From the interview reports, four out of the five interviewees were able to explain at least two instances in which the video-based instruction enhanced their learning of solid mensuration concepts:

M05: *The videos helped me to visualize things much well than imagining the shapes and solid figures made thinking very easy in order to have much time to solve questions.*

M10: *With the videos, I realized that it is not everything we have to be chewing and pouring. With the visual aspect, sometimes I get to imagine certain things to remember how a solid shape looks like without having to always be thinking too far because I have seen it.*

Furthermore, interviewees explained instances where the video-based instruction enhanced their generalization of formulas by comparing one solid shape surface area or volume measurement to another, and four of them were able to elaborate on at least two examples:

M05: *Comparing the curved surface area of a cylinder to derive the formula for the surface area of a sphere. The curved surface area of the cylinder is the area of the opened rectangle. Multiplying the length (circumference of the circle of radius, r), $2\pi r$ by the height, h gives $2\pi rh$ as curved surface area of the cylinder. The curved surface area of the sphere becomes $2\pi r \times 2r = 4\pi r^2$, where $h = 2r$ is the height/diameter of the sphere.* This very example was also explained by students M10, M23 and M43.

M33: *The volume relationship between cone and sphere. Two cones were able to fill one sphere, since the volume of a cone is $\frac{1}{3}\pi r^2 h$, so the volume of 2 cones will be $\frac{2}{3}$ times the base area $\times$ height, so the volume of the sphere will be $\frac{4}{3}\pi r^3$, where $h = 2r$.*

Students **M05** and **M43** correctly explained how the volume of a square prism and square pyramid with the same base area and height are related:

M05 *and* ***M43*:** The *volume of the square pyramid is $\frac{1}{3}$ of the volume of the square prism.*

Interview questions 10 (b) and (c) were to evaluate interviewees' ability in relating both conceptual and procedural knowledge of solid mensuration to solve the problem. Interviewees' oral explanation and written responses demonstrated their understanding. They understood that the same volume of the sand in conical form was poured into the rectangular pit. They therefore equated the two solid figures volume relations and computed for the depth of sand in the pit (see Figure 9 and Appendix I).

10 (b) ***Oral Understanding***

By finding the volume of the cone and the volume of the rectangular prism, you equate the two volumes. Because the volume of the sand that was used to fill the volume of the cone is equal to the volume of the rectangular prism, we then find the height by equating them. So we will make h the subject. The volume of a cone is $\frac{1}{3}\pi r^2 h$ *and the volume of the rectangular prism is base area × height.*

Written Understanding

6. Volume of a Cone = Volume of a rectangular Prism

$\frac{1}{3}\pi r^2 h = BA \times h$

$\frac{1}{3}\pi r^2 h = L \times B \times h$

where $\pi = \frac{22}{7}$

$\frac{1}{3}\pi r^2 h = 2.4m \times 1.9m \times h$

$\frac{1}{3} \times \frac{22}{7} \times (1.5)^2 \times 2 = \frac{114}{25} \times h$

$\frac{33}{7} m^3 = \frac{114h}{25}$

$33 \times 25 m^3 = 7 \times 114h$

$\frac{825 m^3}{798 m^2} = \frac{798h}{798}$

$1.0338m = h$

The depth of sand in the pit = 1.0338m

= 1.03m (2d.p)

Figure 9. Excerpt and snapshot of student M23 answer to question 10 (b).

To determine the area of land covered by the sand in conical form, interviewees realised that circular base was in contact with the land and for the rectangular jumping pit; they understood that the sand was in contact with the five rectangular earth surfaces with the top opened. Figure 10 shows excerpt and snapshot of student M23 answer to this particular question:

10 (c) ***Oral Understanding***

Cone*: The circular section of the cone.*

Rectangular Jumping Pit*: The 5 surfaces of the rectangular prism.*

The surface area of a rectangular prism is 6 but the sixth one has been taken off, that is the topmost part has been taken off.

Written Understanding

Cone

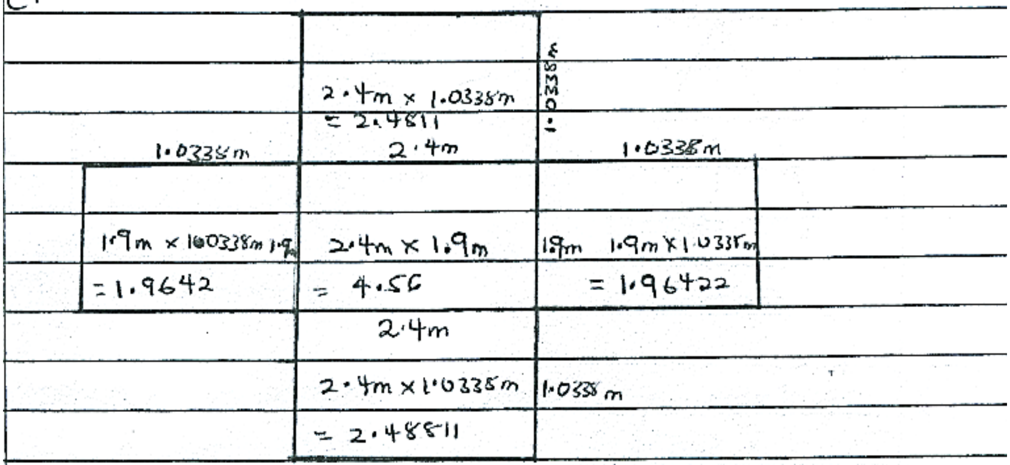
Area of the circular region $= \pi r^2$

$= \frac{22}{7} \times (1.5)^2 m^2$

$= 7.0714 m^2$

$= 7.07 m^2$ (2d.p)

C.



Surface area $= 2(2.4811) + 2(1.9642) + 4.56$

$= 4.9622 + 3.9284 + 4.56$

$= 13.4566$

∴ Area of land coverd by the sand $= 13.4566 m^2$

Figure 10. Excerpt and snapshot of student M23 answer to question 10 (c).

The interviewees' oral and written responses to the interview question 10, clearly indicates that they have developed conceptual knowledge in solid mensuration.

***Real-Life Connections*:** In the following excerpts, some of the interviewees commented that lessons centred on practical application in the context of real-life experiences and examples, which made learning realistic, interesting and valuable to the students.

M23: *It makes me understand the real-life system when it comes to solid mensuration and the use of videos make me understand the way and manner to use the volume and surface area to identify a solid shape.*

M33: *It gives a practical picture of what we learnt by relating it to real-life situation. The videos gave an actual visual of real-life of an object that would be calculated for area or total surface area or volume.*

Altogether, the qualitative data results from the interview and written task worksheets reports corroborate the findings from the quantitative data results. At this point, it clearly suggests that the use of the video-based instruction contributed immensely to the students' spatial ability and conceptual knowledge in solid mensuration, that is, video-based instruction bettered their relational understanding of solid mensuration.

Research question 2: What is the effect of video-based instruction on students' attitudes toward learning solid mensuration?

***Quantitative data*:** Students' views on their attitudes toward learning with video-based instruction before and after instruction were grouped into four and analysed. *Behavioural Engagement* meant how students acted when learning solid mensuration through video-based instruction. *Affective Engagement* looked into how students experienced the teaching and learning of solid mensuration. It had to do with students' interest in learning solid mensuration, their enjoyment of the lessons and satisfaction in working on activities and tasks during lessons. *Solid Mensuration Confidence* looked into students' confidence in learning and understanding solid mensuration. This was based on students' ability in explaining and justifying their understanding to solid mensuration tasks. *Solid Mensuration with Videos* looked into reasons for students' likes and dislikes for the lessons on solid mensuration taught with video-based instruction.

Table 9 presents the results on comparing students' attitudes toward learning with video-based instruction before and after instruction.

Table 9: Paired Sample t-test of M Students' Attitude to Learning with Video-Based Instruction (N=43)

Attitude	Before Instruction		After Instruction		*p* value	Effect Size (*d*)
	M	*SD*	*M*	*SD*		
Behavioural Engagement	1.14	0.227	3.21	0.612	0.0001	3.26
Affective Engagement	1.37	0.350	3.57	0.305	0.0001	5.13
Solid Mensuration Confidence	1.43	0.363	3.71	0.244	0.0001	4.82
Solid Mensuration with Videos	1.37	0.387	3.72	0.360	0.0001	4.53
Overall Attitude	**1.33**	**0.235**	**3.55**	**0.250**	**0.0001**	**6.28**

From Table 9, it is interesting to note that the students' mean attitude to learning with video-based instruction improved significantly after the instruction on all the sub-attitudinal constructs. The overall mean attitude before instruction (M = 1.33, SD = 0.235) and after instruction (M = 3.55, SD = 0.250), t (42) = 31.58, $p < 0.001$ also showed significant difference. Cohen's d was estimated at 6.28, which is a large effect. This suggests that the students acknowledge that they developed positive attitude towards learning solid mensuration.

Qualitative data**:** Each interviewee was asked the following questions: *whether you liked learning solid mensuration with video-based instruction*; *which of the nine lessons taught did you liked most and disliked*, and *can you confidently answer solid mensuration problem at any moment and perform well*.

They all commented that they liked learning solid mensuration and student M23 added on that the lessons were interesting. Surface area and volume of both polyhedron and non-polyhedron were liked by most of the interviewees. Three interviewees said lessons 7 and 9 were quite challenging, because some of the concepts were quite difficult to understand. For instance:

M10*: I disliked the lesson on Finding Lengths and Angles inside Solid Shapes, because I couldn't really understand no matter how hard I tried. So I didn't really like it.*

M05*: I didn't actually dislike any topic, but some were very difficult to understand along the line. Example the Frustum was a bit challenging.*

M43*: In fact, a frustum is a cut off of the solid shapes so finding their ratios was very difficult for me.*

The interview data results revealed that the students liked learning solid mensuration. The results obviously confirm the quantitative data results. This seems to suggest that the students in school M showed positive attitudes toward the use of video-based instruction in learning solid mensuration.

Research question 3: What is the effect of video-based instruction on students' tendency to collaborate in learning solid mensuration?

Quantitative data: Table 10 presents results of the analysis on students' perception of their tendency to collaborate in learning with video-based instruction, before and after instruction.

Table 10: Paired Sample t-test of M Students' Collaborative Learning of Solid Mensuration (N=43)

Collaborative Learning	Before Instruction		After Instruction		*p* value	Effect Size (*d*)
	M	*SD*	*M*	*SD*		
Social Benefits	1.49	0.379	3.58	0.300	0.0001	4.11
Psychological Benefits	1.46	0.357	3.30	0.403	0.0001	3.17
Academic Benefits	1.45	0.426	3.75	0.223	0.0001	4.71
Overall Collaborative Learning	**1.47**	**0.363**	**3.54**	**0.248**	**0.0001**	**4.45**

Clearly, the paired sample *t*-test results in Table 10 indicate that there was significant difference in all the sub-constructs measuring students' perception of the collaborative learning context. The overall perception also showed a significant mean difference before instruction (M = 1.47, SD = 0.363) and after instruction (M = 3.54, SD = 0.248), t (42) = 29.15, $p < 0.001$, with large effect size (Cohen's d = 4.45). Hence, the results suggest that the students in this school acknowledged that they effectively collaborated in learning solid mensuration using video-based instruction.

Qualitative data: The interviewees shared their opinions on these two issues: (a) the use of group work, and (b) the use of small and whole class discussions; in the lessons taught. According to Gokhale (1995), in collaborative learning the success of one student helps other students to be successful. These are the responses by some of the interviewees:

M05*: The discussion was good because if there are necessary corrections that needed to be made, the instructor tells us and it helps us to learn from ourselves.*

M23*: It makes one who doesn't understand; get it better rather than studying alone. I like the whole class discussion because it makes one understand the way and manner the other groups used their methods and formulas and that brings understanding.*

M33*: Working in groups is the best thing I have ever experienced because it made me acquire more knowledge and if I didn't understand anything a colleague student teaches me to get it better.*

All the interviewees pointed out that the collaborative learning environment helped them academically.

On an interesting note, some of the interviewees pointed out that the collaborative learning environment improved their socialization.

M10*: I liked it because I get a lot more people explaining the stuffs, then depending on the group I find myself in; everybody had the way they explained things for me to understand.*

M23*: It's interesting because it brings our socialization role that is if I'm not free with this person, through this group study, we understood each other and we were able to solve problems that were given to us.*

On the psychological benefits, two interviewees acknowledged that collaborative learning reduced anxiety and consequently increased their self-esteem. ***M23****: It enabled us to shun away shyness and express ourselves to our fellow friends.*

M33*: It made our group to shun away shyness and made us more courageous working in the midst of our colleagues.*

The qualitative results corroborate the quantitative results. Thus, the use of video-based instruction was effective in promoting collaboration among students in learning solid mensuration.

At this point, the qualitative data results have substantiated and validated the quantitative data results from school M; this provides some insights to help answer the three research questions of the study. However, the results from school M alone do not provide a holistic picture of the topic under consideration. The next section therefore examined the same issues from the perspective of school N.

School N Data Analyses Results

The results of the quantitative data analysis from the 39 participants responses to the before and after instruction questionnaire and lessons tests scores are presented in this section, followed by the qualitative results from five of the interviewees' reports and written work scripts. The same procedures used in school M was followed through.

Research Question 1: What is the effect of video-based instruction on students' relational understanding of solid mensuration?

Quantitative data: The results in Table 11 compare students' self-assessment of their learning and understanding of solid mensuration, before and after instruction. There were greater mean scores in all the after instruction measurements as compared to the before instruction, showing that the students acknowledged that the instructional medium was effective in promoting their relational understanding at the end of the instructions.

Table 11: Paired Sample t-test of N Students' Self-Assessment of their Relational Understanding of Solid Mensuration (N=39)

Relational Understanding	Before Instruction		After Instruction		*p* value	Effect Size (*d*)
	M	SD	M	SD		
Spatial Ability of Solid Shapes	2.26	0.354	3.47	0.348	0.0001	3.03
Conceptual Knowledge of Solid Mensuration	1.55	0.265	3.41	0.313	0.0001	4.84
Real-Life Connections	1.65	0.439	3.46	0.349	0.0001	3.28
Overall Relational Understanding	**1.82**	**0.298**	**3.45**	**0.272**	**0.0001**	**4.49**

Significance level, $\alpha = 0.5$; Degrees of freedom, $df = 38$

The results as illustrated in Table 11 indicates that there was a significant mean difference in the overall mean students' relational understanding before (M = 1.82, SD = 0.298) and after (M = 3.45, SD = 0.272), t (38) = 28.10, p <

0.001 the instruction. Cohen's *d* was estimated at 4.49, which is a large effect size. This positive outcome suggests that video-based instruction contributed significantly to the students in school N relational understanding of solid mensuration.

To comprehend the students' performance in the lessons tests taken, descriptive statistics were derived as shown in Table 12.

Table 12: Descriptive Statistics of N Students' Lessons Tests Scores

n	Min. Score	Max. Score	Median Score	Mode Score	Mean Score	SD	Skewness	Kurtosis
39	6.00	10.00	7.75	7.86	7.73	0.81	0.07	0.81

From Table 12, the mean score of the students' performance was 7.73 (0.81), with 20 students (51.28%) scores above the mean score; with range 4.00. The skewness value -0.02 and kurtosis value 0.01 are approximately normally distributed. The results suggest that the use of video-based instruction accounted for the remarkable performance of the students. This affirms the students' self-assessment on the effectiveness of video-based instruction in promoting relational understanding of solid mensuration.

Qualitative data: Results of the analysis of the interviewees' reports and written work scripts were compared with the quantitative results. The interviewees responded to interview Questions 2, 8 and 10. The Question 10 was real-life context and the interviewees responded to it orally and in writing, which was scored.

From Table 13, lessons tests score of two of the interviewees were above the class mean score of 7.73. However, the scores of all the five interviewees improved considerably on the solid mensuration task, with the least score as 9.33.

Table 13: School N Interviewees' Scores in Lessons Tests and Interview Task

Students	Gender	Lessons Tests Score	Solid Mensuration Task Score
N34	Male	8.78	9.33
N33	Female	7.89	10.00
N13	Male	7.67	10.00
N15	Male	7.11	9.67
N22	Male	7.11	9.33

Interviewees' responses showed clear understanding of the solid mensuration task. Those who scored below 10.00 forgot to leave their final answer(s) to two decimal places as stated in the question or they could not identify more than three properties of cone or cuboid.

Spatial ability of solid shapes: On question 10 (a), interviewees' were asked to: *Oral Understanding;* (a) Identify the properties of each solid shape in the given information, and *Written Understanding*: (a) Draw and name each solid shape in the given information. Figure 11 shows excerpt and snapshot of student's N13 answer. The interviewee was able to identify and mention properties of both the cone and cuboid, and also drew and labelled them correctly. The other interviewees were able to answer the questions correctly (see Appendix J).

10 (a) ***Oral Understanding***

***Cone**: one vertex, one curved surface and a circular base.*
***Cuboid**: 8 vertices, 6 surfaces, 12 edges and cross sectional is a rectangle.*

Written Understanding

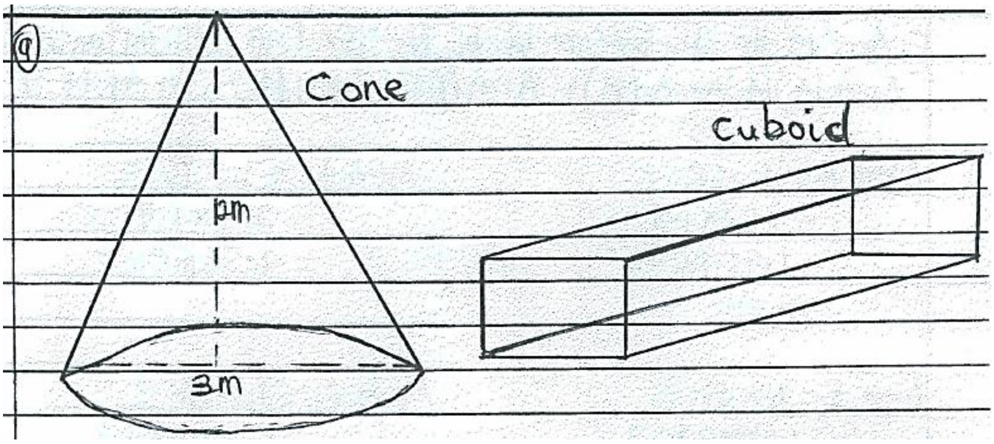


Figure 11. Excerpt and snapshot of student N13 answer to question 10 (a).

The results from interview data have evidently shown that the use of video-based instruction enhanced the students' development of spatial ability of solid shapes.

Conceptual knowledge of solid mensuration: Interviewees' answers to interview Questions 2, 8 and 10 (b) and (c), as captured in the interview guide were used to ascertain the effectiveness of the video-based instruction in developing students' conceptual knowledge in solid mensuration. The following comments were from some of the interviewees in response to how the video-based instruction helped them in learning solid mensuration.

N15: *It has helped me very well with the use of videos and the objects we used make me remember all that we learned the other day. I remember the formulas of the solid figures and how to draw the net of the objects.*

N22: *For the videos, it's like watching a movie. When you watch a movie, it sticks in your brains and you are able to recall the movie and tell it to others,* *so using the videos, how to arrive at certain formulas and answers will stick into your mind.*

N33: *It showed the real pictures and the views of the objects we were about to learn and it helped us to calculate.*

The interview Question 8 required that interviewees mention examples and further explain how the video-based instruction enhanced their generalization of solid mensuration concepts. The interviewees gave explicit examples and precise explanations to this question. For instance, students N13, N15 and N22 were able explain the volume relation between cone and cylinder:

N13*: I learnt that three times the volume of the cone will give you the volume of the cylinder. The volume of the cylinder is $\pi r^2 h$, where $\pi r^2$is the base area, then one cone will be the volume of the cylinder divided by three. So its formula is $\frac{1}{3}\pi r^2 h$.*

Students N13 and N22 correctly explained the relationship between the surface area of sphere and the curved surface area of a cylinder:

N13*: The area for the curved surface of a cylinder was the same as the area for the curved surface area of a sphere. For a cylinder it is $2\pi rh$. The height of a cylinder divided by two will give you the radius of the sphere so the height of the sphere is equal to $2r$. So it will become $4\pi r^2$ which is the surface area of a sphere.*

Student N15 was able to explain the volume relation connecting all the prisms (e.g., cube, cuboid, cylinder) and volume relation between a prism and its corresponding pyramid (e.g., square prism corresponds with square pyramid):

N15: *Calculating the volume of a prism ..., it tells you to calculate the base area × height, so in case the base area is of a circular pattern, use the formula for the area of a circle, to get $\pi r^2 \times h$ as the volume of the circular prism.*

Three times the volume of a pyramid is equal to one prism. The volume of one pyramid becomes $\frac{1}{3}$ base area × height.

Another generalization was on the volume relation between the sphere and cone. This was student N33 explanation:

N33: *I remember when a sphere was put there and water was put in the cone fully, two of the cones filled the sphere. For the volume of the sphere, we added $\frac{1}{3}$ of the cone to $\frac{1}{3}$, where the volume of the cone is $\frac{1}{3}\pi r^2 h$. So twice that will be $\frac{2}{3}\pi r^2 h$. To relate it to the volume of the sphere, the h was the diameter and two of the radius is one diameter so it became $\frac{4}{3}\pi r^3$.*

The interviewees' answers (both oral and written) to interview Questions 10 (b) and (c) were used to further examine their conceptual knowledge of solid mensuration. Figures 12 and 13 illustrate excerpts and snap shots of written work of student N34 on the questions.

10 (b) ***Oral Understanding***

The pile of sand which was in the form of a cone was poured into a rectangular pit so to get the depth of the sand; we are supposed to compare the volume of the cone to that of the rectangular prism which is the jumping pit. The volume of the cone will be equal to the sand being poured into the jumping pit if only it fills the pit.

Written Understanding

b. Volume of cone $= \frac{1}{3}\pi r^2 h$

$= \frac{1}{3} \times \frac{22}{7} \times (1.5)^2 \times 2$

$= 4.7143\,m^3.$

The volume of the cone is same as volume of the sand filled in the rectangular jumping pit.

∴ The depth of the sand in the pit is

$V = L \times B \times H$, $L = 2.4m$, $B = 1.9m$, $H = ?$

$V = 2.4 \times 1.9 \times H$

$\frac{4.7143}{4.56} = \frac{4.56H}{4.56}$

$H = 1.0338\,m^3$

$H = 1.03\,m^3$

∴ The depth of the ~~land~~ sand in the pit is 1.03 m

Figure 12. Excerpt and snapshot of student N34 answer to question 10 (b).

10 (c) ***Oral Understanding***

***Cone**: The area of the cone which was covering the land is the circular base.*
***Rectangular jumping pit**: When it was transferred into the rectangular pit, the area that was covering the land was the base area and the sides of the pit. The sides are 4 so the 4 sides and the base area will be 5.*

Written Understanding

Area of land covered by the base area of the cone

$A = \pi r^2$

$= 22 \times (1.5)^2 = 7.07m^2$

Area of the land covered by the Sand in the jumping pit

Base area of rectangular pit.

$L \times B = 2.4 \times 1.9 = 4.56m^2$

$B \times H = 1.9 \times 1.03 = 1.957 \times 2 = 3.914m^2$

$L \times H = 2.4 \times 1.03 = 2.472 \times 2 = \cancel{6.82m^2}\ 4.944m^2$

Total area of the land covered by the Sand in the jumping pit by the sand in the jumping pit

$A = 4.56 + 3.914 + 4.944$

$A = 13.418$

$A = 13.42\ m^2$

Figure 13. Excerpt and snapshot of student N34 answer to question 10 (c).

The results on both the interviewees' oral and written answers indicate that they have substantially developed conceptual knowledge on solid mensuration concepts. They exhibited deep reasoning and understanding in their responses to their interview questions, especially when they were answering the real-life solid mensuration task. These positive outcomes could be attributed to the potency of the video-based instruction.

Real-Life Connections: The following excerpts expresses students N13 and N33 views when I asked them to identify ways the videos helped them in learning solid mensuration.

N13: *The Drawing of the Solid shapes and Net surfaces made me to know the real surface that the object has so in calculating let's say the area, you just find the area of each surface and sum them together.*

N33: *It showed the real pictures and the views of the objects we were about to learn and it helped us to calculate.*

From their responses, they observed that the video-based lessons were practical and related to their real-life experiences.

Up to this point, the qualitative data results have confirmed the quantitative data results. This indicates that the use of video-based instruction contributed greatly to the students' development of relational understanding of solid mensuration concepts.

Research question 2: What is the effect of video-based instruction on students' attitudes toward learning solid mensuration?

Quantitative data: The students' responses to the questionnaire items before and after instruction in solid mensuration were grouped into four sub-constructs and analysed. Table 14 shows the results of the statistical analysis of the paired sample *t*-test and effect size values on students' attitude towards the use of video-based instruction in learning solid mensuration, before and after the instruction.

Table 14: Paired Sample t-test of N Students' Attitude to Learning with Video-Based Instruction (N=39)

Attitude	Before Instruction		After Instruction		*p* value	Effect Size (*d*)
	M	*SD*	*M*	*SD*		
Behavioural Engagement	1.47	0.523	3.08	0.542	0.0001	2.03
Affective Engagement	1.67	0.517	3.53	0.291	0.0001	3.17
Solid Mensuration Confidence	1.64	0.553	3.49	0.304	0.0001	2.65
Solid Mensuration with Videos	1.53	0.479	3.56	0.291	0.0001	3.43
Overall Attitude	**1.58**	**0.429**	**3.41**	**0.233**	**0.0001**	**3.59**

From Table 14, the students' attitude to learning solid mensuration improved significantly on all the categories considered. Furthermore, the overall mean students' attitude before (M = 1.58, SD = 0.429) after (M = 3.41, SD = 0.233), t (38) = 22.44, $p < 0.001$ instruction revealed a significant difference, with large effect size (Cohen's d = 3.59). This indicates that the students developed positive attitudes to the use of video-based instruction in learning solid mensuration.

Qualitative data: The following excerpts are on interviewees like and dislike for the solid mensuration lessons. They all mentioned that they liked the lesson on *Drawing Solid Shapes and Net Surfaces*. Students N13 and N22 added on that they also liked the lesson on *Frustum, Similar and Changed Solid Shapes*. Moreover, the lesson on *Volume of Surface Area of Composite Solid Shapes* was preferred by Student N15 and *Finding the Lengths and Angles inside Solid Shapes* was preferred by Student N34. The following are excerpts from the interview with some of the interviewees:

***N13**: The Drawing of the Solid shapes and Net surfaces. It made me to know the real surface that the object has so in calculating let's say the area, you just find the area of each surface and sum them together. The other one I like was the Frustum and the similar and changed solid shapes. Because after that lesson, I went through my textbook and I saw similar examples and solved and it made me to like that topic.*

***N22**: Drawing Solid Shapes and Net Surfaces. I wasn't good at the art but through the use of the videos, it was able to teach me how to draw using certain dimensions.*

***N34**: Finding the lengths and Angles inside solid shapes. I liked that one too because finding the length and angles inside solid shapes when it was shown to me on the screen, I captured it and I understood it so I loved to do it.*

The interviewees also identified some concepts that they could not easily comprehend.

N33: *I didn't understand the lesson Surface Area of Non-Polyhedrons.*

N34: *I did not dislike any of the topics but it was very challenging. The topic was the volume of the Non-Polyhedrons. I did not understand it very well. But I will continue to revise to get a better understanding.*

So far, the interviewees' comments have also shown that the students liked learning with video-based instruction. The results therefore compare favourably and confirm the quantitative results. On the whole, the students in school N have shown positive attitudes to the use of video-based instruction in learning solid mensuration.

Research question 3: What is the effect of video-based instruction on students' tendency to collaborate in learning solid mensuration?

Quantitative data: Table 15 illustrates a paired sample t-test results to compare students' views on their engagement in collaborative learning and corresponding Cohen's *d* effective size values, before and after instruction.

Table 15: Paired Sample t-test of N Students' Collaborative Learning of Solid Mensuration (N=39)

Collaborative Learning	Before Instruction		After Instruction		*p* value	Effect Size (*d*)
	M	*SD*	*M*	*SD*		
Social Benefits	1.68	0.415	3.38	0.320	0.0001	3.12
Psychological Benefits	1.67	0.398	3.25	0.376	0.0001	2.57
Academic Benefits	1.59	0.410	3.47	0.229	0.0001	3.71
Overall Collaborative Learning	**1.65**	**0.370**	**3.37**	**0.251**	**0.0001**	**3.40**

As illustrated in Table 15, there was a significant mean difference in students' views toward the use of collaborative learning before (M = 1.65, SD = 0.370) and after (M = 3.37, SD = 0.251), t (38) = 21.24, $p < 0.001$ instruction. The estimated Cohen's d = 3.40 indicates a large effect. This implies that the use of video-based instruction significantly promoted collaboration among the students in learning.

Qualitative data: The interviewees expressed their views on the use of group work and small and whole class discussions during lessons. The following remarks were made by some of the interviewees on the social benefits of the collaborative learning settings enacted in the lessons:

N22*: At first, I didn't know how to study in groups but during the lessons, I was put in different types of groups so that we share ideas and learn how to arrive at certain answers, so it helped me to associate with friends.*

N34*: I think it was very good, because we learnt how to associate with people when doing group work.*

These were some of the interviewees' comments on the psychological benefits gained from collaborative learning experiences:

N22*: It boosted my morale. I wanted to always solve it for others to see.*

N34*: Some of the group members made you feel that the points you raised were more important to them so it made you feel that you are good.*

Lastly, on the academic benefits of collaborative learning, interviewees indicated that they were able to share and exchange ideas with their colleagues during lessons. For examples;

N13*:* L*et's say, a question has been asked and I have no idea about it, when my colleagues get up and answer, I take that answer if the teacher confirms that the answer is correct, I take the answer and learn it.*

N15*: When we were solving on the board and there is any mistake our other colleagues in different groups tell us that this one is a mistake, so we find out the mistakes in our work.*

At this stage, the analysis results on students' views on the frequent use of team work and small/whole class discussions in the solid mensuration lessons are consistent with the quantitative data results. Both the quantitative and qualitative results suggested that the use of video-based instruction in learning was effective in promoting collaborative learning among the students of school N.

Students' Views on the Students' Activities Sheet in Lessons

The students' activities sheets were intended to serve two purposes: to sequence lesson instruction and serve as students' worksheet (see Sample at Appendix G). First, to sequence the teaching and learning activities, the information on each sheet was aligned and tailored to the lesson plan and that of the PowerPoint slides order of instructional activities. According to Wyels (2015), the Mathematical Association of America cited the following as the goals in using worksheets: (a) helping students focus on an underlying big picture (b) bridging the gap between watching and doing (c) focusing students' attention in class (d) delivering and/or summarizing content efficiently (e) encouraging students to communicate their mathematical ideas (f) teaching students how to learn from their textbooks (g) connecting new material to previously-covered material.

The activities sheet was new to the students, and it therefore added a new dimension to their learning experience. For this reason, I was interested in knowing how it contributed to their learning. So, the interviewees were asked to comment on the question: *Did you like the use of the activities sheet in the lessons? Why?* Some of the school M interviewees' answers are as follows:

M05: *It helped me to be much engaged in the question since you would have to fix yourself in a group in order to solve the questions that you are given and it helps you have a summary of everything you have been taught in the lesson.*

M33: *After each activity, it helps me to practice more. It also guided our learning in an orderly manner.*

M43: *In the visual aspect, we were not able to put down information so when the activity sheet was given to us, it made us recall what we have seen.*

Some of the School N interviewees responded in this manner:

N13: *Yes, because when the sheets are given to us, there are some examples on it and when the video tells us that we should solve for some examples, we are able to follow up the activity sheet and solve it accordingly.*

N15: *Yes, there were some questions and examples on the sheets so when the video tells us to work for an exercise or a try work on the sheet, we solve it on the sheet we know that what we are doing is right.*

N22: *It gives you some questions to solve on your own so that you check your answers with that of the videos.*

N34: *It made me concentrate, because what is shown on the screen will not give you the answer straight away, it will only show you how you go about it.*

The responses suggest that the activities sheet helped the students to practice more examples, guided their learning in an orderly manner and it summarised the lessons. It also enabled the students to concentrate during instructions; therefore, it engaged and sustained their interest in the lessons. Another significant finding was that, it contributed to students' collaborative learning. These findings are in line with the goals of Wyels (2015) on the use of worksheets in class.

Deductions from the results of schools M and N

In general, the analyses of both the quantitative and qualitative data sets collected from the two schools in studying the same research problem yielded similar results for all the three research questions. The quantitative results showed significant high mean difference in favour of the after instruction on all the three constructs measured, with large effect. Lessons tests score on students' performance in solid mensuration was remarkable. In comparing the two separate data sets, the qualitative results substantiated and validated the quantitative findings, indicating that the video-based instruction had positive effect on students' relational understanding, their attitudes, and tendency to collaborate in learning solid mensuration. On the whole, the results provide enough information to help answer the three research questions of the study in the next section.

Discussion of Results

The most significant results identified in this study and how they corroborate the reviewed literature are discussed under the following headings in relation to the research questions.

The effect of video-based instruction on students' relational understanding of solid mensuration

In this study, students' relational understanding of solid mensuration was based on their ability to integrate both procedural and conceptual knowledge (Arsal, 2009) of solid mensuration concepts. Hence, students were to demonstrate both their oral and written understanding to solid mensuration concepts and skills. This research question was aimed at examining students' relational understanding of solid mensuration under the categories: *Spatial*

Ability of Solid Shapes, *Conceptual Knowledge of Solid Mensuration* and *Real-Life Connections*. It is interesting to note that both the quantitative and qualitative data analysis results from the two intact classes revealed that the students recognised that the video-based instruction promoted their relational understanding in all the three categories.

Another significant positive finding was the effectiveness of the video-based instruction and physical manipulatives in promoting students' relational understanding of solid mensuration in a way that they did not develop difficulties and misconceptions, at least those reported in the literature when it comes to students' learning of solid mensuration. The literature reviewed on students' difficulties and misconceptions when studying solid mensuration pointed out the following. Students have difficulty in visualizing and reasoning 3D shapes in 2D representations (Aszalos & Bako, 2004; Dreyfus & Hadas, 1991; Owens & Outhred, 2006; Patkin, 2015). However, the participants in this study were comfortable when visualizing and reasoning 3D shapes in 2D representations. This positive finding could be as a result of the videos, cut-out models and realia of solid shapes; that were incorporated in the instructional design.

Prior to the instructional session, the students manipulated the geometric-solid cardboard nets to construct the solid models, which were subsequently used in most of the lessons. By this means, students' visual and spatial reasoning of 2D and 3D figures improved considerably. The use of the videos helped students to compare and relate surface area and volume formulas. More so, the videos helped the students to vividly and clearly see the sectional views of the solid shapes when they were learning and solving questions.

In the literature, it was evident that students find it difficult in describing and transcribing 3-dimensional figure based on observing it in space (Patkin, 2015; Denenberg, 2011; Maida, 2005). In this study, I observed that few of my students encountered this problem. In the second lesson, *Drawing Solid Shapes and Net Surfaces*, these students drew a circle to represent a sphere. Also, when drawing the net surfaces for the following: cubes, cuboids, triangular prisms and rectangular pyramids, due to the oblique and isometric views of the objects both on paper and screen, the students drew rhombus and parallelogram to represent the square and rectangular faces respectively. However, with the available solid-shaped models, these misconceptions were easily corrected to the extent that students did not repeat them in subsequent lessons. In the case of the sphere, I asked them to look at a spherical object (table tennis ball) and the sketch of the sphere in their diagrams sheet. In the other instances, I asked the students to identify the respective solid-shaped models from the collections available. After examining the surfaces again, they understood that the surfaces were basically triangular, square and rectangular shapes as compared to how they initially thought. Through that, they were able to correct their mistakes.

Another compelling finding of this study was that the students developed a connected understanding of concepts. Students were able to explain the relationships and connections among the different solid mensuration contexts and concepts they studied. Consequently, the following connections were established by interviewees: (a) connecting the relationship between the volume measurements of prisms and pyramids, (b) connecting the relationship among volume of cylinder, cone and sphere, (c) connecting the surface area of cylinder to sphere, (d) recognising that surface area of a given solid shape is sum of individual areas of the net solid, (e) establishing that the general volume relation of solid shapes is the product of base area by height, and (f) realising that when the same quantity of substance is used to fill different solid shapes, their volumes are same.

In this respect, the performance of students from both schools was good, for the reason that the literature reports showed that students at times misquote the appropriate formulas when learning and working on solid mensuration tasks. For instance, the WAEC Chief Examiners' report on Core Mathematics paper 2 (e.g., 2014, 2015), Denenberg (2011), Obara (2009), Özerem (2012) reported that students have difficulty in memorizing, recalling or quoting and manipulating of solid mensuration formulas. However, the study findings showed that students developed a conceptually connected understanding of solid mensuration concepts, so they were at ease in comparing and relating concepts and formulas.

Another noteworthy finding was on students' ability in establishing relationships in terms of similarities and patterns among the surface area and volume measurements of the various types of solid shapes. Hence, students were not found to be rehearsing and memorising formulas and procedures for solving solid mensuration problems. Instead, they developed both conceptual and procedural understanding, in such a way that the two forms of understanding complemented each other in the concepts and skills presented (Ministry of Education, Ontario, 2004). The students' contributions and written work output to the assignments they were given, both in class and the interview session indicated that the enacted designed lessons helped them to grasp the intended relational connections on solid mensuration.

The present findings are consistent with other research that used audio-visuals on students' learning outcomes (Ode, 2014; Quarcoo-Nelson, Buabeng & Osafo, 2011; Igbojinwaekwu (n.d.); Allen, 2007). The findings of this study further confirm earlier research findings that used virtual manipulatives as instructional technology on students' learning of solid geometry (Baki et al., 2011; Dimakos & Zaranis, 2010; Fletcher & Anderson, 2012; Gambari et al., 2014; Gittinger, 2012; Hwang et al., 2009; McClintock et al., 2002).

Finally, the results on students' relational understanding of solid mensuration corroborate the ideas of Kinach (2002) on teaching for relational understanding of mathematics. Kinach opined that "to the teacher who embraces a relational view of mathematics, student achievement is much broader than remembering. Problem posing, critical and contextual thinking, the ability to justify and represent one's thinking mathematically are all part of what mathematics achievement means" (p. 54).

Students' attitudes to learning with video-based instruction

The purpose of the second research question was to examine students' views regarding their attitudes toward the use of video-based instruction in learning solid mensuration. In the data analysis, both the quantitative and qualitative data sets were organised and categorised under the following headings: *Behavioural Engagement*, *Affective Engagement*, *Solid Mensuration Confidence* and *Solid Mensuration with Videos*. The results of the data analyses from the two independent schools confirmed that the students showed positive attitudes to learning with video-based instruction.

To begin with, on the behavioural engagement, the results of the data collected through students' questionnaire responses showed that the mean difference between the before and after instruction was statistically significant. This implies that there was a substantial difference in the students' behavioural engagement during and after the teaching of solid mensuration. I also observed during lessons that the students were ready, willing to learn what they were being taught and consequently participated in activities and discussions. In general, students were enthusiastic and engaged in learning solid mensuration. Eshun (2004) contended that positive attitudes towards mathematics are desirable since they may influence one's readiness and willingness to learn and benefit from mathematics instruction (p. 2).

Considering students' affective engagement towards learning solid mensuration, there was a statistically significant mean difference between the before and after instruction questionnaire results. These findings are consistent with the findings from the students' interview reports, as the majority of the students expressed their satisfaction and enjoyment in learning solid mensuration using video-based instruction. The findings are supported by that of Curtis' (2006) study. Curtis conducted a study in which cooperative learning, problem solving, discourse and the graphing calculator were used as the standards-based pedagogy. The study established that students found the class enjoyable; anxiety was reduced as students became more familiar with the instructional strategies; and students recognized the value of mathematics.

Students' confidence to learning solid mensuration was examined based on their ability in explaining and justifying their understanding of solid mensuration concepts. During the teaching and learning process, I observed that majority of the students were capable of thinking critically and justifying their responses when answering or giving contributions within their group or whole class discussions. More so, the results from interviewees' responses to questions that elicited their understanding of solid mensuration concepts suggested that students were confident in learning solid mensuration. These findings confirmed the quantitative findings, which indicated that there was positive significant mean difference between students' mean difference before and instruction. These positive findings on students' confidence when learning solid mensuration, thus affirms the views of Yara (2009), Eshun (2004) and Curtis (2006). According to Yara, teachers with positive attitude, towards mathematics can stimulate favourable attitudes in their students. Eshun argued that students' positive attitude towards mathematics is an indication that they can be effectively assisted to learn mathematics when provided with the environment that motivates them by building their confidence in doing mathematics and lessen their anxiety. The study by Curtis found that cooperative learning, problem-solving, discourse, and graphing calculators increased student confidence in doing mathematics.

Regarding the use of video-based instruction in presenting the concepts in solid mensuration, the findings showed that the instructional medium had significant influence on students, in terms of their positive attitudes toward learning and understanding solid mensuration. The questionnaire data result was statistically significant in terms of students' gains. The results so far suggest that majority of the students liked learning with video-based instruction; though it was their first time to learn mathematical concepts with technology-based instruction.

The present findings are supported by past studies which found that students showed positive attitudes to learning mathematics with technology. For instance, the present study adapted the *Mathematics and Technology Attitudes Scale* (MTAS) developed by Pierce et al. (2007). In their study, they found that most of students surveyed agreed that it was better to learn mathematics with technology. Similarly, the study by Barkatsas et al. (2009) also used the MTAS. Their findings indicated that high achievement in mathematics was associated with high levels of confidence in mathematics, strongly positive levels of affective engagement and behavioural engagement, high confidence in using technology and a strongly positive attitude to learning mathematics with technology. Other studies have also shown that teaching mathematics with technology positively impacted students' attitude and academic performance (e.g., Boyraz, 2008; Ellington, 2003 & Shin et al., 2012).

Video-based instruction promoting collaborative learning

The designing and enactment of the solid mensuration lessons were based on the ideas of enactivism pedagogy. It advocates for partnership between teachers and students in the classroom. In an enactivist classroom, "the teacher does not seek to facilitate nor direct the pupils in what to do and think, but promotes participation and genuine interaction to encourage learning" (Proulx, 2009, p. 275). Teachers co-author knowledge with students by guiding students' attention towards the intended goals (Li et al., 2010).

To this, my interest was to engage students in collaborative learning. As a collaborator, I was an active participant in the teaching-learning process, in which I provided rich learning activities and guided the students towards co-evolving patterns during the teaching and learning of solid mensuration using video-based instruction. I mostly employed group-centred instruction, group and whole class discussions and hands-on activities. This teaching environment made the students responsible for one another's learning as well as their own (Gokhale, 1995).

The results from the quantitative which were confirmed by qualitative results revealed that, to a large extent, the implementation of collaborative learning in the study benefited students socially, psychologically and academically. These findings corroborate earlier literature that found that the integration of technology to mathematical lessons promoted collaborative learning. For instance, Laal and Ghodsi (2012) observed that collaborative learning helps to develop a social support system for learners. Psychologically it increases students' self-esteem and reduces anxiety. Academically it promotes critical thinking, involves students' actively, motivates them in learning and improves their results.

D'souza and Wood (2003) also observed that collaborative learning had an overall positive effect in the cognitive, social and affective domain in mathematics. In Gokhale's (1995) study, the students who participated in collaborative learning performed significantly better on the critical-thinking test than those who studied individually. Similarly, the study by Chandra (2015) also reported of higher achievement scores of students in collaborative learning than individual learning methods.

Chapter Summary

The instructional sequence in this study was effective in that students developed both procedural and conceptual understanding of solid mensuration concepts which formed the basis of their relational understanding of solid mensuration. The students established the following generalizations and connections on solid mensuration: (a) polyhedrons have flat faces and straight edges, but non-polyhedrons have flat and curved faces or curved face only, with curved edges (b) given a prism and a pyramid with both having congruent base (same base shape and size) and same height, their volumes are related (c) cylinder, cone and sphere of same circular base and height have related volumes (d) the curved surface of a cylinder and sphere of same circular base and height have same surface area.

These positive developments were probably beyond what students would have gained by using the traditional teacher-centred approach, which is typically based on the use of paper, pen and calculator, in teaching and learning solid mensuration. It is therefore worth mentioning that the most beneficial aspect of using video-based instruction was that it: developed students' spatial ability; established similarities and pattern; and developed conceptual connections by relating one concept to another. Thus, students' concepts development was built up from manipulation, visualisation, drawing figures, effective discussion, participation in group work, and hands-on activities.

Again, the instructional approach provided diverse teaching experience for the students. The instant playback, rewind, forward and pause features of the videos allowed the students to learn at their own pace. The videos also added variation and clarity to classroom discourse. That is, the researcher's and students' voices were not dominating instructional discourse. Rather, we were always attentive to watch and listen whenever a video was screened. The videos, realia and use of real-life questions, constantly brought the abstract concepts to life, which made students recognise and connect solid mensuration to everyday life. In general, the findings suggest that the video-based instruction contributed significantly to the students' relational understanding of solid mensuration.

The interview reports on all the four categories underlining students' attitude to learning solid mensuration seemed to be consistent with the students' positive perception of their attitude to learning solid mensuration. It was in the case of *Solid Mensuration with Videos* where interviewees' responses were a bit inconsistent on their like and dislike for the lessons they experienced. For example, on the topic: *Frustum, Similar and Changed Solid Shapes*, four out of the ten interviewees reported that it was the lesson they liked most, but three said they disliked the *frustum* aspect. However, those interviewees who disliked any of the lessons reported that those lessons were a bit difficult for their understanding. Even so, they said they would still learn and understand those aspects.

The findings on the implementation of collaborative learning also showed that students recognised that the video-based instruction promoted collaborative learning among them. In effect, there has been a substantial development in the students' critical thinking skills and justification of their knowledge on solid mensuration ideas.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Overview

This chapter provides a summary of the entire study, by revisiting the purpose of the study, the research questions and key findings from the research. The contributions of the study findings to knowledge in the field of mathematics education in general, and more specifically to the teaching and learning of mathematics in Ghanaian Senior High Schools were also discussed. Lastly, recommendations and suggestions were made for further research to strengthen the findings of this study.

Summary of the Study

This study was necessitated as a result of the lack of literature on the use of video-based instruction on the teaching and learning of mathematics and findings on students' attitudes toward learning solid mensuration with the particular instructional technology researchers have used in their studies. Again, the study was necessitated out of curiosity to explore the effect of video-based instruction on students' difficulties in learning and understanding of solid mensuration, due to the fact that most of the previous studies used virtual manipulatives.

Therefore, the study explored the effectiveness of video-based instruction, with physical manipulatives on students' relational understanding, their attitudes toward the use of video-based instruction and their tendency to collaborate, in learning solid mensuration; in the Birim Central Municipality. A mixed methods concurrent triangulation design embedded with one-group pre-test and post-test quasi-experimental design was employed. Thus, the two intact classes, one from each school were simultaneously studied. The results were compared and qualitative results were used to validate the quantitative results in finding answers to the research questions.

The findings of this study do not only make significant contributions to knowledge in its immediate discipline, but also contributes to the wider body of knowledge where other disciplines could benefit from. This study has shed light on the potential of video-instruction on the teaching and learning of mathematics. As a result, the product of this research, *Module for Teaching Solid Mensuration using Video-Based Instruction*, could be used to complement the traditional teacher-centred approach, through which solid mensuration concepts are most often taught in schools.

Before the start of my study, I could not find any account of research that answers the very research questions posed by this study using the research design and approaches carried out in this study. Thus, this study to some extent will help fill the void in the lack of research on video-based instruction in mathematics. The findings also point to the fact that, the enactivist pedagogy, which promotes the existence of collaboration between teachers and students in the classroom, is a better approach for teaching and learning mathematics, which must be encouraged in Ghanaian classrooms.

Key Findings

From the results of this study, the following findings were obtained:

Research Question 1: What is the effect of video-based instruction on students' relational understanding of solid mensuration?

The video-based instruction had significant positive effect on students' relational understanding of solid mensuration. They were able to demonstrate that video-based instruction contributed significantly to their development of spatial ability and conceptual knowledge of solid mensuration and further disclosed that the instructions were connected to real-life situations and examples. There was statistically significant mean difference in each of the categories in the quantitative results. The results from the individual interviews also shed light on the quantitative data results.

Research question 2: What is the effect of video-based instruction on students' attitudes toward learning solid mensuration?

In this study, it became clear from the results that the students developed and exhibited positive attitudes toward the use of video-based instruction in learning of solid mensuration. The findings from the interview reports on all the four categories on students' attitude to learning solid mensuration threw more light on the quantitative results on students' positive perception of their attitude to learning solid mensuration.

Research Question 3: What is the effect of video-based instruction on students' tendency to collaborate in learning solid mensuration?

The questionnaire data results indicated a statistically significant difference in the students' perception on video-based instruction promoting collaborative learning. The students' interview reports also showed that the video-based instruction boosted collaborative learning; these findings well explain and confirm the questionnaire data findings. Thus, the students acknowledged that the video-based instruction promoted collaborative learning; which benefited them socially, academically and psychologically.

The following are the findings from the interview reports on the use of students' activities in the lessons. The activities sheets which contained practice questions; helped the students to solve more questions which enhanced their understanding of the solid mensuration concepts. It guided their learning in an orderly manner and summarised the salient information in the lessons. It also enabled the students to focus in the lessons and sustained their interest. Another significant finding was that, it encouraged the students to communicate their mathematical ideas.

Conclusions

Firstly, the video-based instructional design was effective in promoting students' integrated understanding of solid mensuration concepts, as they were able to compare and relate concepts in the topic. Thus, their spatial ability and conceptual knowledge in solid mensuration were greatly developed. As a result, they did not encounter many difficulties nor develop misconceptions in the topic, at least those reported in the literature. The real-life context through which the lessons were related to made students to recognise and connect solid mensuration to everyday life.

Secondly, the instructional and interaction contexts through which the lessons were implemented promoted positive attitudes toward learning and motivation. Students found the lessons enjoyable; their interests were aroused; they were less anxious when they became more familiar with the instructional setting; and they developed confidence in answering questions and contributing to discussions. On the whole, the students liked the way and manner they were taught and learned solid mensuration. The students' activities sheets provided hands-on for the students, this engaged their attention and interest in lessons.

Lastly, the findings brought to light that the students benefitted socially, psychologically and academically from the collaborative learning strategies that were implemented in this study.

Recommendations

Despite the limitations of this study, the findings from this study raise some significant matters relating to the teaching and learning of mathematics. Consequently, I would offer the following recommendations to enhance the on-going reforms on associated benefits of integrating technology into teaching to improve students' learning and interest.

Towards the full realisation of integrating technology-based instruction in classrooms, particularly in Ghana, I call on teachers to design and enact innovative teaching and learning which foster students' engagement and relational understanding of mathematical concepts. Teachers should as much as possible connect mathematical lessons to everyday life to help students value and develop interest in mathematics. The Ghana Education Service, Parent-Teacher Association and school authorities should provide motivational packages to award teachers who integrate technology in their lessons to promote the use of technology-based instruction in schools.

The findings on students' positive attitudes towards the studying of solid mensuration provide some useful information for teachers. They should enact lessons within favourable instructional and interactional contexts "to help build students' confidence by encouraging the belief that everyone can "do" mathematics … helping students to appreciate the value of mathematics in their lives" (Ministry of Education, Ontario, 2004, p. 24).

From the policy perspective, the results from this study also contribute to the realisation of the objective of promoting cooperative learning among students' as stated in the mathematics curriculum. The results showed that the use of collaborative learning strategies benefited students greatly. It must however be noted by curriculum developers, school authorities and teachers that its benefits are usually long term. Hence, "Examination marks may not increase immediately but using properly structured group work … can help the students to reflect more on their work" (D'souza & Wood, 2003, p. 8).

In this study, it was evident that some of the students had difficulties in understanding *Frustum* concepts. To better students' comprehension, I recommend the lessons sequence illustrated in Table 17, to enable them have more examples to solve on *Frustum* concepts and pace the lesson.

Table 16: Prescribed Solid Mensuration using Video-Based Instructions Lessons Sequence for Future Consideration

Lesson	Sub-Topic/Content
1	Introduction to Solid Mensuration
2	Drawing Solid Shapes and Net Surfaces
3	Surface Area of Polyhedrons
4	Surface Area of Non-Polyhedrons
5	Volume of Polyhedrons
6	Volume of Non-Polyhedrons
7	Finding Lengths and Angles inside Solid Shapes
8	Volume and Surface Area of Composite Solid Shapes
9	Surface Area and Volume of Frustum/Truncated Pyramids
10	Surface Area and Volume of Similar and Changed Solid Shapes

Suggestions for Further Research

While this study has demonstrated the effectiveness of the use video-based instruction, it should be noted that the instructional approach reported in this study is new. In this regard, there is considerable need for further research to strengthen and further elaborate on the findings and also contribute to its literature. The present study was limited to only: one municipality, two schools with one intact class from each school. The study was also conducted on an aspect of geometry—solid geometry; however, geometry is just one of the domains of mathematics. Conducting a similar study in other places and topics would contribute to the study findings.

Although the teaching approach reported here may be rejected by some educators and teachers because it may seem expensive and time consuming when it comes to getting the resources, preparation and even the enactment of the lessons. Nevertheless, if students gain a strong understanding as a result of such instructional approach at this level, it may help them to understand more advanced solid geometry concepts easily in their future studies. Some future research should shed light on this aspect.

On the final note, it is worth mentioning that the study reported in this thesis is easy to replicate. In future, more intact classes from more schools could be considered with a control group. Similar studies could be done on the effect of video-based instruction in other mathematics topics (e.g., plane mensuration, angle properties and measurements in plane figures, angles of elevation and depression, transformation) and other subject areas that are deemed to be abstract or difficult for students to comprehend.

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APPENDICES

APPENDIX A

INTRODUCTORY LETTER

DEPARTMENT OF SCIENCE AND MATHEMATICS EDUCATION

E-mail: dsmeducation@gmail.com
TELEGRAMS & CABLE
UNIVERSITY, CAPE COAST
TELEPHONE.
OFFICE: 03321-34890

COLLEGE OF EDUCATION STUDIES
UNIVERSITY OF CAPE COAST
CAPE COAST, GHANA

DEPT. OF SCIENCE AND MATHEMATICS EDUCATION

Our Ref.: DSME/P.3/V.1/15   Date: 16th December, 2015

Your Ref.:

TO WHOM IT MAY CONCERN:

Dear Sir/Madam,

RESEARCH VISIT

The bearer of this letter, **MR. ASIAMAH OSMOND AMPONSAH**, with registration number ED/MDP/14/0006 is an M.Phil (Mathematics Education) student of the Department of Science and Mathematics Education, College of Education Studies, University of Cape Coast.

As part of the requirements for the award of an M.Phil degree, he is required to undertake a research visit to your school with the purpose of collecting data on the topic **"USING AUDIO-VISUALS ON SENIOR HIGH SCHOOL STUDENTS' RELATIONAL UNDERSTANDING IN SOLID MENSURATION".**

I would be grateful if you could give him the necessary assistance he may need.

Thanks for your usual support

Yours faithfully,

Prof. Eric M. Wilmot
HEAD

APPENDIX B

STUDENTS' INFORMATION AND CONSENT FORM

Students' Information and Consent Form

Title of Project: Using Audio-Visuals on Senior High School Students' Relational Understanding of Solid Mensuration

Name of Researcher: Asiamah Osmond Amponsah

Dear Student,

Would you consider taking part in some research?
I am planning to do some research to investigate how the use of audio-visuals can improve S.H.S. students' relational understanding of solid mensuration. I would like you to take some time to read the following information to understand why the research is been done and decide if you would take part or not.

What is the Purpose of the Study?
The purpose of this research is to examine how audio-visuals can improve students' relational understanding of solid mensuration. The study also wishes to examine the effect of audio-visual instructions on students' attitudes toward the learning of solid mensuration and whether it support collaborative learning among students in learning solid mensuration.

Who is asked to take part and why have I been chosen?
All S.H.S. students in the Birim Central Municipality are invited to take part in the study. You have been chosen to take part because your school, likewise your class has been selected for the study.

What will happen if I take part?
If you choose to be included, you will be asked to take part in lessons on solid mensuration using audio-visuals, complete some questionnaires and you may be selected for interview if you agree.

What are the possible benefits of taking part?
After completing the study I will provide you with a summary of the results if you wish to. The information that you provide will also help educational authorities in improving the quality of teaching and learning of mathematics in our schools through the integration of ICT.

Confidentiality – What will happen to the information I provide?
When I write up the study everyone's name and the names of schools will be changed so that no one can be identified. Also any information which may lead to identifying the schools or the students will be removed from the final write up. If you have any questions do not hesitate to ask. If you would like to participate, please complete the next section.

Student's Consent
I confirm that I have read and understand the participant information for the above mentioned research project. I understand my participation is voluntary. I also understand my responses will be made anonymous (treated as confidential). I hereby agree to take part in the above mentioned research project.

[redacted]	....	16/1/2017
(Name of Participant)	(Signature)	(Date)
[redacted]	....	16/1/17
(Name of Witness)	(Signature)	(Date)
Asiamah Osmond Amponsah	....	16/01/17
(Name of Researcher)	(Signature)	(Date)

Thank you for reading and completing this form.

APPENDIX C

BEFORE INSTRUCTION QUESTIONNAIRE

This questionnaire is divided into four sections A, B, C and D and you are expected to honestly complete all the sections on this form.

SECTION A: BIOGRAPHIC DATA

1. Your age (in complete years):………… **2.** Gender: Male [ ] Female [ ]

SECTION B: STUDENTS' RELATIONAL UNDERSTANDING OF SOLID MENSURATION

Complete the statements below on your expectations of how the use of video-based instruction will improve your learning and understanding of solid mensuration.

Please tick [✓] in ***only one*** of the appropriate column for your response to the following statements.

Note: **SA** = Strongly Agree, **A** = Agree, **D** = Disagree, **SD** = Strongly Disagree

№	**Statement**	**SA**	**A**	**D**	**SD**
1	The video demonstrations and simulations will help me gain enough understanding of the concepts in solid mensuration				
2	The use of the activities worksheet in the lessons will help me to understand the concepts of solid mensuration better				
3	Manipulating the paper cut-out to change 2D into 3D shapes and vice versa will make the lessons real and understandable				
4	The examples and exercises given in the lessons will enhance my understanding of solid mensuration concepts				
5	The activities worksheet will help me to follow the lessons and think critically in understanding the lessons				
6	I will be able to relate the concepts learned to real life situations				
7	The use of the videos demonstrations will help to identify patterns, compare and relate ideas to make generalisations				
8	The use of the videos and power point presentations will motivate my learning and understanding				
9	The individual tests will help me to check my understanding in the lessons				
10	Sketching 2D and 3D forms will help me to visualise and understand the details of the solid figures				
11	Relating the lessons to real life by using physical manipulatives will help me to understand the concepts in the lessons better				
12	The videos will help me to visualize the concepts in solid mensuration very well				
13	It will be easier to learn and understand solid mensuration concepts using the video-based instruction				
14	The use of the physical manipulatives will make the concepts in solid mensuration real, concrete and understandable				
15	I will have enough understanding in solid mensuration and I will be able to confidently answer problems on it without difficulty				

SECTION C: STUDENTS' ATTITUDES TOWARD LEARNING WITH VIDEO-BASED INSTRUCTION

Complete the statements below on how you think your attitudes towards the learning of solid mensuration concepts through the use of video-based instruction will be.

Please tick [✓] in ***only one*** of the appropriate column for your response to the following statements.

Note: **NA** = Nearly Always, **Us** = Usually, **Oc** = Occasionally, **HE** = Hardly Ever

№	**Statement**	**NA**	**Us**	**Oc**	**HE**
1	I will be able to concentrate very well in solid mensuration lessons				
2	I will try to answer questions the teacher asks in solid mensuration lessons				
3	If I make mistakes in the solid mensuration lessons, I will work until I have corrected them				
4	If I can't solve a solid mensuration problem, I will keep trying different ideas				

Note: **SA** = Strongly Agree, **A** = Agree, **D** = Disagree, **SD** = Strongly Disagree

№	**Statement**	**SA**	**A**	**D**	**SD**
5	I will surely score more than half of the score in the solid mensuration tests				
6	I know I will be able to handle difficulties in solid mensuration problems				
7	I will be confident with learning solid mensuration				
8	I will be interested to learn new things in solid mensuration				
9	In the solid mensuration lessons I will get rewarded for my effort				
10	Learning solid mensuration will be enjoyable				
11	I will get a sense of satisfaction when I solve solid mensuration problems				
12	I will like learning solid mensuration all the time				
13	Spending extra time learning solid mensuration will be worth the extra effort				
14	The way solid mensuration will be taught will make it very interesting				
15	The way solid mensuration will be taught will help me learn solid mensuration concepts better				

SECTION D: VIDEO- BASED INSTRUCTION ON COLLABORATIVE LEARNING OF SOLID MENSURATION

Complete the statements below on how you think the video-based instruction will promote collaborative learning among you the students in learning solid mensuration. Please tick [✓] in **only one** of the appropriate column for your response to the following statements.

Note: **SA** = Strongly Agree, **A** = Agree, **D** = Disagree, **SD** = Strongly Disagree.

№	**Statement**	**SA**	**A**	**D**	**SD**
1	I will enjoy the lesson more when I work with other students				
2	My group members will help explain things that I will not understand				
3	My group members will respect my opinions				
4	When I work in a group I will be able to share my ideas				
5	My group members will make me feel I am as smart as they are				
6	The lesson will be easier to understand when I work with other students				
7	My group members will like to help me learn the lesson				
8	The workload will be usually less when I work with other students				
9	Our job will not be done until everyone has finished the assignment				
10	I do not find it difficult to express my thoughts when I work in a group				
11	I will try to make sure my group members learn the material				
12	I will like the students I am assigned to work with				
13	I will not let the other students do most of the work				
14	I will like to work with students whether or not they will be smart as I am				
15	When I work in a group, there will be opportunities to express my opinions				
16	We will not be able to complete the assignment unless everyone contributes				
17	My marks will improve when I work with other students				
18	I will help my group members with what I will be good at				
19	The lesson will be more interesting when I work with other students				
20	I will like to help my group members learn the lesson				
21	I will learn more information when I work with other students				
22	I will also learn when I teach the material to my group members				
23	I will not become frustrated when my group members do not understand the assignment				
24	Everyone’s ideas will be needed if we are going to be successful				
25	When I work with other students, we will not spend too much time talking about other things				

Thank you for your cooperation and response.

APPENDIX D

AFTER INSTRUCTION QUESTIONNAIRE

This questionnaire is divided into four sections A, B, C and D and you are expected to honestly complete all the sections on this form.

SECTION A: BIOGRAPHIC DATA

1. Your age (in complete years):………… **2.** Gender: Male [ ] Female [ ]

SECTION B: STUDENTS' RELATIONAL UNDERSTANDING OF SOLID MENSURATION

Complete the statements below on your assessment of how the use of video-based instruction improved your learning and understanding of solid mensuration.

Please tick [✓] in ***only one*** of the appropriate column for your response to the following statements. **Note**: **SA** = Strongly Agree, **A** = Agree, **D** = Disagree, **SD** = Strongly Disagree

№	**Statement**	**SA**	**A**	**D**	**SD**
1	The video demonstrations and simulations helped me gain enough understanding of the concepts in solid mensuration				
2	The use of the activities worksheet in the lessons helped me to understand the concepts of solid mensuration better				
3	Manipulating the paper cut-out to change 2D into 3D shapes and vice versa made the lessons real and understandable				
4	The examples and exercises given in the lessons enhanced my understanding of solid mensuration concepts				
5	The activities worksheet helped me to follow the lessons and think critically in understanding the lessons				
6	I can relate the concepts learned to real life situations				
7	The use of the videos demonstrations helped to identify patterns, compare and relate ideas to make generalisations				
8	The use of the videos and power point presentations motivated my learning and understanding				
9	The individual tests helped me to check my understanding in the lessons				
10	Sketching 2D and 3D forms helped me to visualise and understand the details of the solid figures				
11	Relating the lessons to real life by using physical manipulatives helped me to understand the concepts in the lessons better				
12	The videos helped me to visualize the concepts in solid mensuration very well				
13	It was easier to learn and understand solid mensuration concepts using the video-based instruction				
14	The use of the physical manipulatives made the concepts in solid mensuration real, concrete and understandable				
15	I now have enough understanding in solid mensuration and I can confidently answer problems on it without difficulty				

SECTION C: STUDENTS' ATTITUDES TOWARD LEARNING WITH VIDEO-BASED INSTRUCTION

Complete the statements below on your attitudes toward the learning solid mensuration concepts through the use of video-based instruction.

Please tick [✓] in ***only one*** of the appropriate column for your response to the following statements.

Note: **NA** = Nearly Always, **Us** = Usually, **Oc** = Occasionally, **HE** = Hardly Ever					
№	**Statement**	**NA**	**Us**	**Oc**	**HE**
1	I concentrated very well in the solid mensuration lessons				
2	I tried to answer questions the teacher asked in solid mensuration lessons				
3	If I made mistakes in solid mensuration lessons, I worked until I have corrected them				
4	If I could not solve a solid mensuration problem, I kept trying different ideas				
Note: **SA** = Strongly Agree, **A** = Agree, **D** = Disagree, **SD** = Strongly Disagree					
№	**Statement**	**SA**	**A**	**D**	**SD**
5	I mostly scored more than half of the score in the solid mensuration tests				
6	I know I can handle difficulties in solid mensuration problems				
7	I am confident with learning solid mensuration				
8	I am interested to learn new things in solid mensuration				
9	In the solid mensuration lessons I got rewarded for my effort				
10	Learning solid mensuration was enjoyable				
11	I get a sense of satisfaction when I solve solid mensuration problems				
12	I like learning solid mensuration all the time				
13	Spending extra time learning solid mensuration was worth the extra effort				
14	The way solid mensuration was taught made it very interesting				
15	The way solid mensuration was taught helped me learn solid mensuration concepts better				

SECTION D: VIDEO-BASED INSTRUCTION PROMOTE COLLABORATIVE LEARNING OF SOLID MENSURATION

Complete the statements below on how the video-based instruction promoted collaborative learning among you the students' in learning solid mensuration. Please tick [✓] in **only one** of the appropriate column for your response to the following statements.

Note: **SA** = Strongly Agree, **A** = Agree, **D** = Disagree, **SD** = Strongly Disagree.

№	**Statement**	**SA**	**A**	**D**	**SD**
1	I enjoyed the lesson more when I worked with other students				
2	My group members helped explain things that I did not understand				
3	My group members respected my opinions				
4	When I worked in a group I was able to share my ideas				
5	My group members made me feel I was as smart as they were				
6	The lesson was easier to understand when I worked with other students				
7	My group members liked to help me learn the lesson				
8	The workload was usually less when I worked with other students				
9	Our job was not done until everyone had finished the assignment				
10	I did not find it difficult to express my thoughts when I worked in a group				
11	I tried to make sure my group members learned the material				
12	I liked the students I was assigned to work with				
13	I did not let the other students to do most of the work				
14	I liked to work with students whether or not they were smart as I was				
15	When I worked in a group there were opportunities to express my opinions				
16	We could not complete the assignment unless everyone contributed				
17	My marks improved when I worked with other students				
18	I helped my group members with what I was good at				
19	The lesson was more interesting when I worked with other students				
20	I liked to help my group members learn the lesson				
21	I learnt more information when I worked with other students				
22	I also learned when I taught the material to my group members				
23	I did not become frustrated when my group members did not understand the assignment				
24	Everyone's ideas were needed if we were going to be successful				
25	When I worked with other students we did not spend too much time talking about other things				

Thank you for your cooperation and response.

APPENDIX E

STUDENTS' INTERVIEW GUIDE

Student's Code No.:………………… **Date of Interview**:……………………

Interview start time:……............... **Interview stop time**:…..................

Duration:……………

INTERVIEW QUESTIONS

1. Did you like the solid mensuration lessons taught with the use of videos and real objects?

2. What way(s) do you think the video-based instruction helped you in your learning of solid mensuration?

3. Which lesson (s) did you like most? Why?

4. Which lesson (s) did you dislike? Why?

5. How did the activities worksheet contribute to your learning and understanding in the solid mensuration lessons?

6. How did you find working in small groups?

7. Did you like the group as well as whole class discussions?

8. Did the video-based instruction help you better in comparing some of the solid mensuration formulas? Mention some examples.

9. Do you think you can now confidently answer solid mensuration questions and perform well in any given test?

10. *Question on Solid Mensuration*

A pile of sand is in the form of a cone of base diameter *3 m* and height *2 m.* It is used to fill a rectangular jumping pit measuring *2.4 m* by *1.9 m.*

Use the information to answer the following questions.

Oral Understanding: I want to hear you answer these questions.

(a) What are the properties of each of the solid shapes in the given information?

(b) Explain how the depth of sand in the pit could be known.

(c) How would you find the area of land covered by the sand in both instances?

Written Understanding: Now answer the following questions on the test sheet.

(a) Draw and name each solid shape in the given information.

(b) What is the depth of sand in the pit?

(c) Find the area of land covered by the sand in both instances.

Correct your final answer to **two** decimal places. Take $= \frac{22}{7}$.

APPENDIX F

SAMPLE LESSON PLAN

1. Lesson Plan Information		
Subject: Core Mathematics	**School M**	**School N**
Form: Three	**Date:**	**Date:**
Topic: Introduction to Solid Mensuration	**Time:** 7:15 pm – 8:35 pm	**Time:** 7:15 pm – 8:35 pm
	Duration: 80 minutes	**Duration:** 80 minutes

2. Instructional Objectives

By the end of the lesson the student will be able to:
(a) explain solid geometry;
(b) identify the number of surfaces, edges and vertices of a given solid shape;
(c) classify and name modeled solid shapes into polyhedron (prisms and pyramids) and non-polyhedron;
(d) classify given solid shapes as having congruent or similar cross-sectional base.

3. Content

(a) Meaning of Solid Geometry
(b) Number of faces, edges and vertices of solid shapes
(c) Classifying solid shapes into:
(i) Prisms, pyramids and others (cylinder, cone and sphere);
(ii) Polyhedron (prisms and pyramids) and non-polyhedron (cylinder, cone and sphere) and
(iii) congruent cross-sectional base (prisms and cylinder) and similar cross-sectional base (pyramids, cone and sphere).

4. Prerequisite Knowledge

- Students are familiar with solid shaped objects around them.
- Students can name and identify the properties of 2D shapes.
- Students can identify 2D shapes that are congruent or similar.

5. Learning Environment

- Computer lab with laptop and projector (including screen)
- Students will be seated in small groups and collaboratively work together to complete assigned tasks. The 43 students in school M will be made up of 10 groups with 4 to 5 members in each group.
  The 39 students in school N will be made up of 10 groups with 3 to 4 members in each group.
- Students will be in their individual seats to take independent test.

6. Resources

- Laptop, Projector (with screen) and External Speaker
- Lesson on PowerPoint slides
- Students' Activities worksheets for collaborative learning
- Models of 3D shapes

7. References

- MoE (2010). Senior High School Teaching Syllabus for Core Mathematics, CRDD – Accra: p. 49

- Korthals G. A. (1998 - 2012). Solid Shapes Nets with Tabs for Folding Retrieved 22nd October, 2015 from: www.korthalsaltes.com
- L1V1: 3D shapes at Mrs Gabby's Environment: https://www.youtube.com/watch?v=his3cU-kslc
- L1V2: How to Describe 3D Figures: https://www.youtube.com/watch?v=6zBUfOtiG-U&t=157s
- L1V3: Naming Solid Shapes: https://www.youtube.com/watch?v=x7-x3b66s08
- L1V4: Practical Examples of Solid Shapes: https://www.youtube.com/watch?v=l75qoUhQDes

8. Teaching & Learning Activities

TIME	TEACHER ACTIVITY	STUDENTS ACTIVITY	EVALUATION
10 mins	INTRODUCTION (a) Put students in assigned groups to undertake lesson activities. (b) Ask students to carefully watch the video L1V1 on solid shaped objects in Miss Gabby's environment.	(a) Students sit together according to their assigned group. (b) Students carefully observe the solid shaped objects in the video.	1. List 5 solid shaped objects you saw from watching the video. 2. List 5 other solid shaped objects apart from what you saw in the video.
15 mins	PRESENTATION *ACTIVITY 1* (a) Let students watch video L1V2, observe and know how solid shapes are described using length, breadth/width and height; including faces, bases, edges and vertices. (b) Task groups to sort out solid models with parallel and congruent polygonal bases. (c) Pick any two of the sorted out models, count and record the number of faces, edges and vertices.	*ACTIVITY 1* (a) Observe video simulation describing solid shapes to explain the term Solid Geometry in relation to 3D figures (b) Observe and manipulate to sort out solid models with parallel and congruent polygonal bases. (c) Identify the number of faces, edges and vertices.	1. Explain the term Solid Geometry. 2. Sort out solid models with parallel and congruent polygonal bases. 3. Count and record the number of faces, edges and vertices of **any two** of the sorted out models.
20 mins	*ACTIVITY 2* (a) Instruct students to watch video on naming solid shapes (L1V3), while watching find out the criteria used in classifying the solids into prisms,	*ACTIVITY 2* (a) Watch video and answer questions posed by the teacher.	1. Which criteria are used to name solid shapes under prisms and pyramids?

	pyramids and the others. (b) Give out the solid models to groups. Task students to collaborate in their respective groups to sort out in classifying and naming the solid shaped models.	(b) Students team up to sort, classify and name the solid models.	2. How different is the cylinder, cone and sphere from the prisms and pyramids? 3. Classify and name the solid shaped models into prisms, pyramids and the others.
10 mins	*ACTIVITY 3* Discuss with class how solid shapes can also be classified as: A. Polyhedron and Non-Polyhedron B. Congruent and similar cross-sectional base	*ACTIVITY 3* Contribute to discussion.	1. Which groups of solid shapes are polyhedrons? 2. Which solid shapes are non-polyhedrons? 3. Which 3D shapes have congruent cross-sectional base? 4. Which 3D shapes have similar cross-sectional base?
25 mins	CONCLUSION (a) Show video on practical solid shapes around (L1V4). (b) Direct students to break up from their groups, sit individually and conduct test to evaluate students understanding of lesson.	(a) Watch video (b) Independently write test and hand over test sheet for scoring and grading.	TEST [15 mins] Answer the questions by providing the needed information to complete the table.

9. Remarks

NOTE: ***Contact through e-mail for copy of all the 10 lessons on CD;*** ***aoamponsah99@yahoo.com***

APPENDIX G

SAMPLE STUDENTS' ACTIVITIES SHEET

Topic: Introduction to Solid Mensuration		Lesson No.: 1			Date:	
Group No.:	Code Nos.					

INTRODUCTION

Carefully watch the video and take notices of the solid shaped objects displayed in Miss Gabby's environment.

1. List 5 solid shaped objects you saw from watching the video.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

2. List 5 other solid shaped objects apart from what you saw in the video.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

PRESENTATION

Activity 1 (a): What is Solid Geometry?

Watch this video carefully and afterwards explain the term Solid Geometry.

…………………………………………………………………………………………

…………………………………………………………………………………………

Activity 1 (b): Describing Solid Shapes

As you keep watching the video (in Activity 1 (a)), take note of the faces, bases, edges and vertices of the object been displayed.

1. Using the solid shaped models, group those with parallel and congruent polygonal bases.
2. Pick **any two** of the grouped solid models, count and record the number of faces, edges and vertices.

Solid Shape	Number of Faces	Number of Edges	Number of Vertices
I			
II			

Activity 2: Naming Solid Shapes

Watch the video and identify how solid shapes are named.

1. How different is the cylinder, cone and sphere from the prisms and pyramids?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

2. Complete the table by naming the solid shaped models into prisms, pyramids and the others.

Prisms	Pyramids	Others

Activity 3 (a): Classifying Solid Shapes into Polyhedron and Non-Polyhedron

Based on the discussion on Polyhedron and Non-Polyhedron, classify solid shapes into:

Polyhedron:

…………………………………………………………………………………………

Non-Polyhedron:

…………………………………………………………………………………………

Activity 3 (b): Classifying Solid Shapes into Polyhedron and Non-Polyhedron

Based on the discussion on solid shapes with Congruent or Similar cross-sectional base, classify solid shapes as having:

Congruent Cross-sectional Base:

…………………………………………………………………………

Similar Cross-sectional Base:

……………………………………………………………………………

CONCLUSION

In this video, observe some of the practical examples of solid shapes in real life.

Evaluation Test

On the given test sheet, answer the questions by providing the needed information to complete the table.

APPENDIX H

SCORING RUBRIC FOR SOLID MENSURATION TASK

Intended Outcome: the interviewee will use spatial ability skills and conceptual knowledge acquired during instructions to solve interview Question 10; by responding orally followed by written response.

	Performance Task	Rating = 3	Rating = 2	Rating = 1	Score
Oral Understanding	(**a**) Properties of Cone	Identify at least three properties	Identify two properties	Identify one property	
	(**a**) Properties of Cuboid	Identify at least three properties	Identify two properties	Identify one property	
	(**b**) Explaining how depth of sand in pit would be known	Clear and concise explanation in relating the volume of cone and cuboid, and making height the subject	Adequate explanation in relating the volume of cone and cuboid	Marginal explanation which does not follow to answer problem	
	(**c**) Finding the base area of cone	Clear and concise explanation to find the base area of cone	Adequate explanation to find the base area of cone	Marginal explanation which does not follow to answer problem	
	(**c**) Finding the area of cuboid with top open	Clear and concise explanation to find the area of cuboid with top open	Adequate explanation to find the area of cuboid with top open	Marginal explanation which does not follow to answer problem	
Written Understanding	(**a**) Draw Cone	—	Clear and labelled diagram of cone	Either name or diagram of cone	
	(**a**) Draw Cuboid	—	Clear and labelled diagram of cuboid	Either name or diagram of cuboid	
	(**b**) Finding depth of sand in pit would be known	Clearly quote and equate volume of cone and cuboid, and evaluate given values to solve problem	Quote volume of cone and cuboid, and evaluate given values	No coherent procedure to solve problem	
		—	Use of clear procedure in solving, with answer to 2 d.p.	No coherent procedure to solve problem	
	(**c**) Finding the base area of cone	Clear and concise procedure to find the base area of cone, with answer to 2 d.p.	Adequate procedure to find the base area of cone without answer to 2 d.p.	No coherent procedure to solve problem	

	(**c**) Finding the area of cuboid with top open	Clear and concise procedure to find area of with top open, with answer to 2 d.p.	Adequate procedure to find the base area of cone without answer to 2 d.p.	No coherent procedure to solve problem	
				Total	
				Overall Score = Total/3	

APPENDIX I

SCHOOL M INTERVIEWEES' REPORT ON INTERVIEW QUESTION 10

Excerpts and Snapshot of Students M10 and M43 Answer to Question 10 (a)

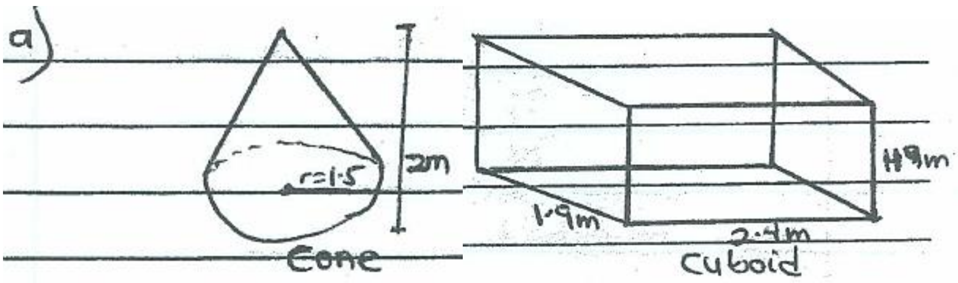
10 (a)

Oral Understanding

***Cone**: circular base, one curved surface, circular edge, one vertex.*

***Cuboid**: 6 flat surfaces, 12 edges, 8 vertices.*

Written Understanding



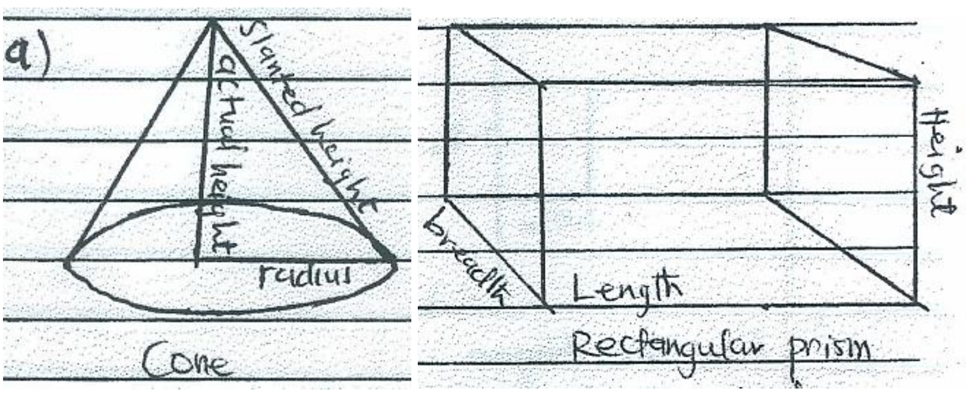
10 (a)

Oral Understanding

***Cone**: circular base, one curved surface, circular edge, one vertex.*

***Rectangular Prism**: 6 flat surfaces, 12 edges, 8 vertices.*

Written Understanding



Excerpts and Snapshot of Students M05 Answer to Question 10 (b)

10 (b)

Oral Understanding

The pile of sand which formed the cone was transferred into the rectangular jumping pit. The two solid shapes will have the same volume. The volume of the cone is one over three pi r squared h and the rectangular prism is the base area times height. You equate the two volumes, make h the subject and evaluate the relation to find h.

Written Understanding

b) $v(\text{cone}) = v(\text{cuboid})$ $d = 3$ $r = 3/2 = 1.5$

$$\frac{1}{3}\pi r^2 h = BA \times H$$

$$\frac{1}{3} \times \frac{22}{7} \times \left(\frac{3}{2}\right)^2 \times 2 = (2.4 \times 1.9)H$$

$$\frac{1}{3} \times \frac{22}{7} \times \frac{9}{4} \times 2$$

$$\frac{396}{84} = \frac{114}{25} H$$

$$\frac{4.7142}{4.56} = \frac{4.56}{4.56} H$$

$$H = 1.0338m \simeq 1.03m$$

$\therefore$ depth of sand in pit is 1.03m

Excerpt and Snapshot of Student M05 Answer to Question 10 (c)

10 (c)

Oral Understanding

***Cone**: circular base*

***Rectangular jumping pit**: sand covered five surfaces with top part not in contact with the land.*

Written Understanding

c) Area of land covered by sand in cone

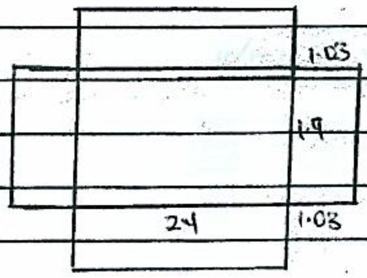
Base area $= \pi r^2$

$\Rightarrow \frac{22}{7} \times \left(\frac{3}{2}\right)^2$

$\Rightarrow \frac{22}{7} \times 9/4 \Rightarrow \frac{198}{28}$

$\Rightarrow 7.07 m^2$

Area of land in rectangular pit covered by sand



$(2.4 \times 1.9) + 2(1.03 \times 1.9) + 2(2.4 \times 1.03)$

$4.56 + 3.914 + 4.944$

$\Rightarrow 13.418 m^2 \simeq 13.42 m^2$

$\therefore$ Area of land covered by sand in rectangular pit is $13.42 m^2$

APPENDIX J

SCHOOL N INTERVIEWEES' REPORT ON

INTERVIEW QUESTION 10

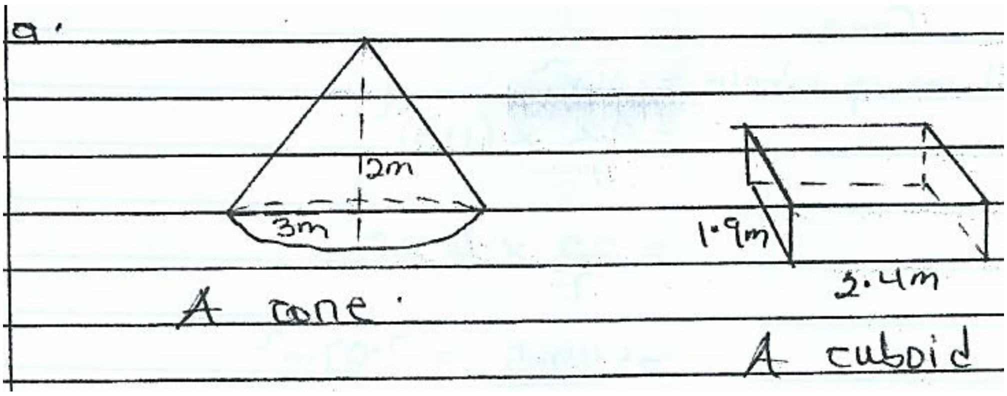
Excerpts and Snapshots of Students N33 and N34 Answer to Question 10 (a)

10 (a) ***Oral Understanding***

***Cone**: a circular base, one vertex, one curved surface and one circular edge.*

***Cuboid**: 6 faces, 12 vertices and 8 edges.*

Written Understanding

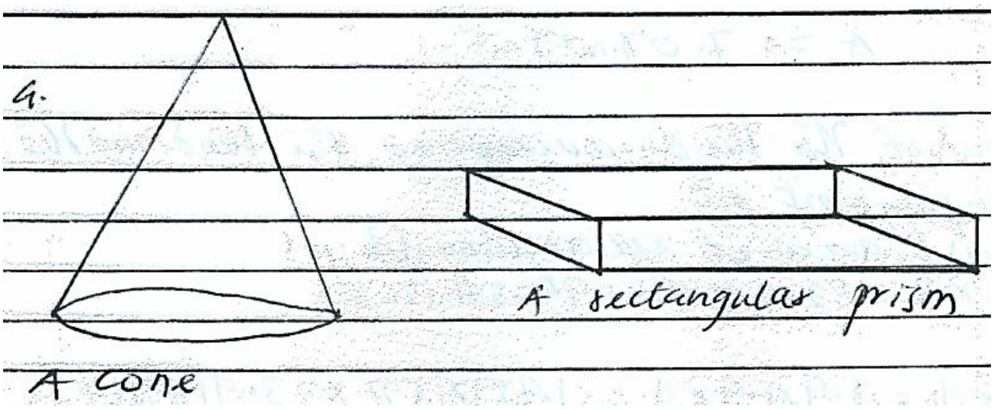


10 (a) ***Oral Understanding***

***Cone**: one curved surface, one circular base and an apex.*

***Rectangular Prism**: two opposite sides facing each other, the two sides are all rectangles; 12 edges; 8 vertices and 6 faces.*

Written Understanding



Excerpt and Snapshot of Students N13 Answer to Question 10 (b)

10 (b)

Oral Understanding

The volume of soil that was in the cone was the same volume that was poured into the pit so calculating the volume occupied by the sand in the pit should be the same as the volume occupied by the sand in the cone. So since we know the formula for calculating the volume of a cone to be $\frac{1}{3}\pi r^2 h$ *and the volume of a rectangular prism to be base × height × length and here we are having the breadth and length so we are left with the height. So we multiply the breadth that we know by the length that we know and by the height which we don't know and equate it to the volume that we have when we calculated for the volume of the cone. So after, we take the volume of the cone and divide it by the base area of the rectangular prism so that we make h the subject of the relation.*

Written Understanding

(b) Volume of sand in the cuboid is the same as the volume of the sand when in the form of a cone.

$\therefore$ ~~Breadth~~ Base area × Height = $\frac{1}{3}\pi r^2 H$

$2{\cdot}4 \times 1{\cdot}9 \times H = \frac{1}{3} \times \frac{22}{7} \times 1{\cdot}5^2 \times 2$

$\frac{4{\cdot}56H}{4{\cdot}56} = \frac{4{\cdot}71}{4{\cdot}56}$

$H = 1{\cdot}0338m$

$H = 1{\cdot}03m$ (2d.p)

Excerpt and Snapshot of Students N13, Answer to Question 10 (c)

10 (c)

Oral Understanding

Cone*: It was a circular base and we know the formula for finding the area of a circle to be* πr^2.

Rectangular jumping pit*: The question is saying that the pit was in the form of a rectangle and a cuboid has 6 surfaces but here, the top surface is not there, it has been removed so we are going to have 5 surfaces to calculate the area and add them up.*

Written Understanding

(c) Area of the Surface covered by the Sand in both instances

Area (A) + Area (B) + Area (C) + Area (D) + Area (E)

Area A = L × B
$= 1.03 \times 1.9$
$= 1.957 m^2$

Area D = L × B
$= 2.4 \times 1.9$
$= 4.56 m^2$

Area B = L × B
$= 1.03 \times 1.9$
$= 1.957 m^2$

Area E = L × B
$= 2.4 \times 1.03$
$= 2.472 m^2$

Area C = l × B
$= 2.4 \times 1.03$
$= 2.472 m^2$

The area is given by
A + B + C + D + E
$1.957 + 1.957 + 4.56 + 2.472 + 2.472$
$\underline{\underline{13.418 m^2}}$
$13.42 m^2$ (2 d.p)

Area of the circle $= \pi r^2$
$= \frac{22}{7} \times 1.5^2$
$= 7.07 m^2$